Universidade de Aveiro Departamento de Educação e Psicologia
Ano 2018

PEDRO FILIPE DA SILVA RODRIGUES

A INFLUÊNCIA DO AMBIENTE VISUAL CIRCUNDANTE EM TAREFAS COGNITIVAS VISUO-ESPACIAIS: UM ESTUDO DESENVOLVIMENTAL

THE INFLUENCE OF THE VISUAL SURROUNDING ENVIRONMENT IN VISUO-SPATIAL COGNITIVE TASKS: A DEVELOPMENTAL STUDY

Universidade de Aveiro Departamento de Educação e Psicologia
Ano 2018

PEDRO FILIPE DA SILVA RODRIGUES

A INFLUÊNCIA DO AMBIENTE VISUAL CIRCUNDANTE EM TAREFAS COGNITIVAS VISUO-ESPACIAIS: UM ESTUDO DESENVOLVIMENTAL

THE INFLUENCE OF THE VISUAL SURROUNDING ENVIRONMENT IN VISUO-SPATIAL COGNITIVE TASKS: A DEVELOPMENTAL STUDY

Tese apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Doutor em Psicologia, realizada sob a orientação científica da Doutora Josefa das Neves Simões Pandeirada, Equiparada a Investigadora Auxiliar do Departamento de Educação e Psicologia da Universidade de Aveiro.

Apoio financeiro da FCT e do POPH/FSE
[Refª. da Bolsa: **SFRH/BD/84279/2012**].

Dedico este trabalho ao meu sobrinho e afilhado, DUARTE.

À minha FAMÍLIA e AMIGOS que são o pilar da minha vida!

A TI, tu sabes quem és e a importância que tens para mim!

o júri

presidente	Professor Doutor António Manuel Melo de Sousa Pereira Professor Catedrático, Universidade de Aveiro
vogais	Professor Doutor Carlos Fernandes da Silva Professor Catedrático, Universidade de Aveiro
	Prof. Doutor Emanuel Pedro Viana Barbas Albuquerque Professor Associado, Universidade do Minho
	Prof. Doutora Luíza Isabel Gomes Freire Nobre Lima Professora Auxiliar, Universidade de Coimbra
	Prof. Doutora Paula Emanuel Rocha Martins Vagos Professora Auxiliar, Universidade Portucalense Infante D. Henrique
vogal - orientadora	Doutora Josefa das Neves Simões Pandeirada Equiparada a Investigadora Auxiliar, Universidade de Aveiro

agradecimentos

Em primeiro lugar, expresso o meu agradecimento público à Doutora Josefa Pandeirada, pelo seu notável trabalho de orientação científica, cunhado por um estímulo permanente, rigor, lealdade, ética profissional e amizade. Pelo seu trabalho constante e muitas vezes discreto, mas fulcral para o desenvolvimento do meu projeto, bem como para a consolidação da Psicologia na Universidade de Aveiro, muito obrigado!
Às instituições de acolhimento do meu programa de trabalhos: Departamento de Educação e Psicologia (Universidade de Aveiro) e IBILI (Universidade de Coimbra).
À entidade financiadora do meu Doutoramento: Fundação para a Ciência e a Tecnologia (FCT).
A todos os participantes desta investigação, que se disponibilizaram a colaborar connosco! Este projeto também é vosso e para vocês!
O meu especial agradecimento a todas as instituições que colaboraram connosco, especificamente: Centros Sociais e Paroquiais de Avanca (Estarreja), de Angeja (Albergaria-a-Velha) e de Santa Joana Princesa (Aveiro), Associação Humanitária de Salreu (Estarreja), Fundação Cónego Filipe de Figueiredo (Estarreja), e Agrupamentos de Escolas de Esgueira (Aveiro) e de Cacia (Aveiro).
O nosso agradecimento é também dirigido a vários patrocinadores que contribuíram com os seus brindes para ofertarmos aos participantes: Porto Editora, Caminho, Fundação Francisco Manuel dos Santos, SEMA, Carlos Santos Hair Shop e Delta Cafés.
Um agradecimento especial à Mind Garden, Inc. (USA) pelo seu patrocínio no âmbito de dois estudos de validação reportados nesta tese.
A todos os Professores e Investigadores do Departamento de Educação e Psicologia da Universidade de Aveiro, pelas sugestões, reflexões, e apoio incondicional demostrados. Aos alunos que colaboraram connosco em algumas tarefas.
Aos meus amigos e colegas, vocês sabem quem são e o quanto contribuíram para este projeto, direta ou indiretamente.
Ao meu irmão afetivo!
À minha FAMÍLIA, pelo amparo e estímulo permanentes!

A TODOS, MUITO OBRIGADO!

palavras-chave

Ambiente circundante visual, ambiente de alta carga visual, ambiente de baixa carga visual, desempenho cognitivo visuo-espacial, distração visual, estudo desenvolvimental, crianças, adolescentes, jovens-adultos, idosos.

resumo
(1/2)

A distração visual é amplamente estudada em diversos grupos etários. Habitualmente, nessas investigações, os estímulos-alvo e os distratores são apresentados no mesmo *display* visual (e.g., no ecrã do computador), um procedimento que parece reproduzir insatisfatoriamente as condições diárias em que atuamos. No nosso dia-a-dia, as tarefas são frequentemente realizadas em ambientes que nos cercam com diversos estímulos visuais; contudo pouco se sabe sobre a sua influência concreta no nosso desempenho cognitivo.
O objetivo principal deste projeto foi desenvolver um procedimento mais ecológico que permita o estudo da distração visual em diferentes grupos etários e que melhor represente as condições que encontramos na nossa vida diária. Para isso, criámos dois ambientes, manipulados de uma forma controlada, onde os participantes realizaram um conjunto de tarefas cognitivas visuo-espaciais básicas. Concretamente, desenvolvemos dois ambientes circundantes, um de alta carga visual e outro de baixa carga visual, nos quais crianças (8-12 anos), adolescentes (13-17 anos), jovens adultos (18-29 anos) e idosos (≥ 65 anos), realizaram as tarefas cognitivas. Seguindo um desenho experimental misto, sessenta e quatro participantes de cada grupo etário realizaram duas sessões individuais com um intervalo entre elas de 14-23 dias; uma das sessões foi realizada no ambiente de alta carga visual, enquanto que a outra sessão foi conduzida no ambiente de baixa carga visual. Em cada sessão, os participantes realizaram duas tarefas de atenção (*go/no-go* e tempos de reação de escolha) e duas de memória (blocos de Corsi e Figura Complexa de Rey). A ordem de aplicação das duas condições ambientais, assim como a ordem de realização das tarefas foi contrabalançada entre os participantes. Alguns instrumentos adicionais foram ainda aplicados para recolha de informação sociodemográfica e para avaliar variáveis individuais (ansiedade-estado, depressão e cronótipo).
Em geral, as crianças, os adolescentes e os idosos apresentaram melhor desempenho quando realizaram as tarefas cognitivas no ambiente de baixa carga visual do que no ambiente de alta carga visual. Especificamente, no ambiente de alta carga visual, as crianças apresentaram menor percentagem de *hits* (*go/no-go*) e de respostas corretas (tempos de reação de escolha), apresentando igualmente maiores tempos de reação a estas últimas; apresentaram ainda menor desempenho nas duas tarefas de memória. Os adolescentes também tiveram pior desempenho no ambiente de alta carga visual; concretamente, neste ambiente os adolescentes apresentaram, nas tarefas atencionais, menor percentagem de *hits* e de respostas corretas, assim como maior percentagem de falsos alarmes e de erros; apresentaram ainda pior desempenho nos blocos de Corsi. Os idosos tiveram também pior desempenho no ambiente de alta carga visual, especificamente com menor percentagem de *hits* e maiores tempos de reação na *go/no-go*, menor percentagem de respostas corretas e mais erros na tarefa tempos de reação de escolha e pior desempenho nos blocos de Corsi. Nos jovens adultos, não verificámos qualquer influência significativa da manipulação ambiental.

(2/2)

Quando analisámos os dados de todos os grupos, os resultados revelaram efeitos principais de grupo etário em todas as variáveis consideradas (tal como previsto), bem como várias interações Ambiente x Grupo-etário. Embora algumas exceções tenham sido encontradas, os resultados descreveram genericamente o padrão habitualmente encontrado nos estudos desenvolvimentais: os idosos e as crianças apresentaram o pior desempenho, seguidos dos adolescentes e finalmente dos jovens adultos que obtiveram o melhor desempenho cognitivo, como esperado. A influência da manipulação ambiental no desempenho cognitivo ocorreu nos três primeiros grupos, tal como expectado. Também apresentamos um breve estudo exploratório, onde averiguámos se o efeito ambiental diferiu quando as variáveis individuais ansiedade-estado, depressão e cronótipo foram consideradas; os resultados nem sempre foram consistentes com as nossas previsões, embora devamos ter cautela com as suas conclusões, dado tratar-se de um estudo puramente exploratório.

O presente trabalho propõe um paradigma experimental alternativo para o estudo da distração visual. Este acrescenta mais validade ecológica, fornecendo resultados que provavelmente refletem mais fielmente o que acontece em contextos reais. Os nossos resultados indicam que a manipulação ambiental realizada afeta o desempenho cognitivo em tarefas cognitivas básicas, particularmente em grupos etários mais vulneráveis à influência de potenciais distratores. Os nossos resultados são discutidos à luz das teorias existentes. Implicações práticas e sugestões para estudos futuros são igualmente avançadas.

keywords

Visual surrounding environment, high-load visual environment, low-load visual environment, visuo-spatial cognitive performance, visual distraction, developmental study, children, adolescents, young adults, older adults.

abstract
(1/2)

Visual distraction is widely studied in different age groups. Usually, in these research, targets and distractors are shown on the same visual display (e.g., the computer screen), a procedure that hardly mimics the everyday conditions in which we operate. We frequently have to perform tasks in environments that surround us with many visual stimuli but little is known about their specific influence on cognitive performance.

The main goal of this project was to develop a more ecological procedure that more closely represented the conditions we face in everyday life to study visual distraction across different age groups. To this end, we created two environments, manipulated in a controlled manner, in which participants responded to a set of basic visuo-spatial cognitive tasks. Specifically, we developed a high-load visual surrounding environment and a low-load visual surrounding environment under which children (8-12 YO), adolescents (13-17 YO), young adults (18-29 YO), and older adults (≥ 65 YO), responded to these tasks. Following a mixed experimental design, sixty-four individuals from each age group participated in two individual sessions with an interval of 14 to 23 days between them: one session was completed in the high-load, whereas the other session was completed in the low-load visual surrounding environment. In each session, participants performed two attentional tasks (go/no-go and choice reaction time) and two memory tasks (Corsi block-tapping and Rey Complex Figure). The orders of the environmental conditions, as well as of the tasks were counterbalanced among participants. Some additional instruments were also applied to collect sociodemographic information and assess individual variables (state-anxiety, depression, and chronotype). Overall, the children, adolescents, and older adults obtained better cognitive performance when the tasks were completed in the low-load as compared with the high-load visual surrounding environment. Specifically, in the later children obtained a lower percentage of hits (go/no-go) and of correct responses (choice reaction time), as well as longer reaction times for the correct responses; they also presented a lower performance in the two memory tasks, when these were performed in the high-load visual surrounding environment. As for the adolescents, when in the high-load environment, they obtained a lower percentage of hits and of correct responses, as well as a higher percentage of false alarms and errors and a lower Corsi span. Performance of the older adults was also lower in the high-load environment, specifically with lower percentage of hits and longer reaction times in the go/no-go task, lower percentage of correct responses and more errors in the choice reaction time, as well as lower performance in the Corsi block-tapping task. Performance of the young adults was not significantly influenced by our environmental manipulation. When the data were analyzed across all age groups, the results revealed main effects of age group in all of the considered variables (as expected), as well as several Environment x Age-group interactions.

(2/2)

Although some exceptions were found, in general, the results described the pattern of results usually found in developmental studies: the older adults and the children presented the lowest cognitive performance, followed by the adolescents, and finally by the young adults who obtained the best cognitive performance, as predicted. The former three groups were also the ones that were influenced by our environmental manipulation, as expected. We also briefly explored if the effect of our environmental manipulation differed when the individual variables of state-anxiety, depression, and chronotype were considered; the findings were not always consistent with our predictions although not firm conclusions should be drawn from these exploratory analyzes.

The current work proposes an alternative experimental paradigm to study visual distraction that more likely reflects what occurs in real settings, adding more ecological validity to this area of research. Our results indicate that such manipulation disrupts performance in basic cognitive tasks, particularly in the age groups that are more vulnerable to the influence of potential distractors. Our results are discussed in light of the existent theories. Practical implications and suggestions for future studies are also mentioned.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

aMEQ	Morningness-Eveningness Questionnaire for adolescents
BDI-II	Beck Depression Inventory-II
CDI	Children Depression Inventory
Combi-TVA	Combined Theory of Visual Attention
GAI	Geriatric Anxiety Inventory
GDS	Geriatric Depression Scale
ICC	Intraclass Correlation Coefficient
ITI	Inter-Trial Interval
MEQ	Morningness-Eveningness Questionnaire
MMSE	Mini-Mental State Examination
PEBL	The Psychology Experiment Building Language
RCF	Rey Complex Figure
SASC	State-Anxiety Scale for Children
STAI	State-Trait Anxiety Inventory
vCRT	Visual Choice Reaction Time
WAIS-III	Wechsler Adult Intelligence Scale - III
WISC-III	Wechsler Intelligence Scale for Children - III

PREAMBLE

"It is not true that *the laboratory can never be like life. The laboratory must be like life!*"

(Gibson, 1979, p. 3).

Understanding humans' cognitive functioning in their everyday life is one of the most important goals of Experimental Cognitive Psychology. Visuo-spatial distraction across the lifespan is a topic that has been of wide interest in this area of Psychology. In these experimental studies, distraction is usually measured by specific cognitive tasks, in which targets and distractors are presented in the same visual display (e.g., on the computer screen). However, little is known about the influence of a visually-enriched surrounding environment on cognitive performance in different age groups, a gap we intend to start fill with the current work. As denoted by James J. Gibson (1979), "*the laboratory must be like life!*" (p. 3), and although our research was not carried out in a *purely natural setting*, we aimed to add more ecological validity to the procedure employed while still making use of cognitive tasks classically administered. The central goal of this PhD project was to investigate whether a high-load *vs.* low-load visual surrounding environment influences cognitive performance (as assessed by basic cognitive tasks) across the development. To this end, groups of children, adolescents, young adults and older adults responded to a set of tasks while being surrounded by a high- and a low-load visual surrounding environment in different times.

This PhD thesis begins with an *Introduction and literature review* (Chapter 1), in which we present the main concepts that support this work, the conclusions of several studies, and identify the gap in the literature that motivated this project. We also present the specific goals and hypothesis for this project. In Chapter 2, we describe global aspects of the *Methodology* used in all studies included in this project. In Chapters 3-5, we present three manuscripts being prepared for submission to international peer-reviewed journals. In Chapter 3, we report the work focused in children aged 8-12 years; the Manuscript is entitled: *When visual stimulation of the surrounding environment impairs cognitive performance: A study with children*. Chapter 4 presents the work conducted with adolescents (ages: 13-17 years) and its title is: *The damaging* *influence of a high-load visual surrounding environment in visuo-spatial cognitive performance: A study with adolescents*. Chapter 5 focuses on the work done with older adults (≥ 65 years old) and young adults (18-29 years old); the Manuscript is entitled *More trouble than good? The influence of the visual surrounding environment in older adults and young adults' cognitive performance*. Of note, Chapters 3-5 refer to manuscripts that were organized in a way to comply with the guidelines (e.g., formatting, number of words, and specific sections) of the international peer-reviewed journals where we aim to submit then for publication. In Chapter 6 (*Integration of the data from all four age groups*), we explored if our predictions regarding cognitive performance across age groups were replicated in our samples and with the specific tasks we used. More importantly, this Chapter presents a developmental analysis of the influence of our environmental manipulation (high- *vs.* low-load visual surrounding environment) in the attentional and memory tasks used in this project by comparing such influence across age groups. Given that several individual variables can influence cognitive performance as denoted in a sub-section of the introductory chapter, such as state-anxiety, depression, and chronotype, in Chapter 7 (*The influence of the visual surrounding environment on cognitive performance after controlling for anxiety, depression, and chronotype*), we explored if the environmental effects described in Chapters 3-6 for each age group differed when each of these variables were considered. In Chapter 8, we present a *General Discussion* of our results, proposing practical implications, and identifying some limitations of our project and suggestions for future studies.

CHAPTER 1.

Introduction and literature review

1.1. Selective attention, inhibition, and working memory for visuo-spatial information: A developmental perspective

In everyday life, we are continuously surrounded by a wide variety of stimuli. Attending and processing all of them is not possible because humans have a limited cognitive capacity (Buschman & Kastner, 2015; Buschman, Siegel, Roy, & Miller, 2011; Oberauer, Farrell, Jarrold, & Lewandowsky, 2016; Peelen & Kastner, 2014). In a complex environment with several stimuli, while some of them are relevant for our ongoing behavior (i.e., target information), others are irrelevant to the task at hand (i.e., distractors) that should be ignored (Forster & Lavie, 2011; Gilbert & Li, 2013). These stimuli can be of different kinds, such as auditory, olfactory, and visuo-spatial (Galotti, 2013). The current work focused on the last ones.

To understand individuals' limited capacity to process external stimuli, a vast number of studies has been conducted and several theories have been proposed. Most of these studies are based on the bottom-up and top-down processing approach (Gazzaley & Nobre, 2012; Gilbert & Li, 2013; Shipstead, Harrison, & Engle, 2012; Theeuwes, 2010). The first allows us to select stimuli according to their features, such as novelty or salience (stimulus-driven selection), whereas the top-down is an active volitional process, that is, stimuli are selected for processing according to our goals (goal-driven selection) (Schreij, Los, Theeuwes, Enns, & Olivers, 2014; Theeuwes, 2010). Since we lack the capacity to process all surrounding stimuli, there are several cognitive processes specialized in selecting important information and in ignoring/inhibiting irrelevant stimuli (distractors), such as selective attention, inhibition, and working memory (Awh, Vogel, & Oh, 2006; Eriksson, Vogel, Lansner, Bergström, & Nyberg, 2015; Gaspar, Christie, Prime, Jolicœur, & McDonald, 2016; Gazzaley et al., 2008; Gazzaley & Nobre, 2012). Given that these constitute three main cognitive processes in which this work is focused, we present next a brief definition of each of them, although it is often difficult to present them as isolated processes because they are closely interrelated (e.g., Gazzaley & Nobre, 2012; Kiyonaga & Egner, 2013).

Selective attention refers to the ability to focus our cognitive resources on information that is important to a given task by filtering irrelevant information (Gazzaley & Nobre, 2012; Lavie, 2010; Lavie, Hirst, De Fockert, & Viding, 2004). Selective attention has been measured by a variety of computerized tasks, such as tasks based on the response-competition paradigm, in which, for instance, a target letter has to be detected among distractor letters (e.g., Lavie, 2005). Another type of tasks frequently used is based on the visual choice reaction time (vCRT) paradigm or response selection paradigm. This type of tasks requires a specific response to each type of stimulus; for example, the participant is instructed to press in a specific button for a given stimulus and in another button for another stimulus (Kroll, Mak, & Samochowiec, 2016; Woods, Wyma, Yund, Herron, & Reed, 2015). A vCRT task involves several stages, such as perceptual analysis, response selection, and response production/motor reaction; in other words, a vCRT requires selection of stimulus and of adequate responses (internal processing), and then the execution of the selected response (motor processing) (for a review, see Kroll et al., 2016). In computerized vCRT paradigms, it is usual to consider several behavioral measures, such as: correct responses, errors, and reaction times. The correct responses[1] occur when participants press the correspondent buttons for the different stimuli. The errors occur when the participant press the button that do not correspond to the stimulus. Reaction times are measured from the onset of each stimulus until a correct response was produced (e.g., Woods et al., 2015).

Inhibition is a crucial executive function that allows us to suppress “actions that are no longer required or that are inappropriate, which supports flexible and goal-directed behavior in ever-changing environments” (Verbruggen & Logan, 2008b, p. 418). It allows us to suppress not only undesirable actions/responses, but also thoughts and emotions (Steele et al., 2013; Verbruggen & Logan, 2008a). Additionally, inhibition (which can be an automatic or a controlled response) requires other cognitive functions, such as selective attention (described above) and working memory (Barrett, Shimozaki, Jensen, & Zobay, 2016; Chikazoe, 2010; Verbruggen & Logan, 2008a). To assess this cognitive function, researchers often administer go/no-go tasks (e.g., Chikazoe, 2010; Simmonds, Pekar, & Mostofsky, 2008). A visuo-spatial go/no-go task requires a specific response to a specific stimulus (e.g., letter *X*), and a non-response/inhibition-response to another stimulus (e.g., letter *K*; Steele et al., 2013). Whereas a go/no-go task requires a specific response to a given stimulus and a non-response to other stimulus, a vCVR requires always *active* responses to all stimuli (e.g., to press in keyboard key “Q” for the red color and to press in “P” to the green color;

[1] The behavioral measures of vCRT tasks are commonly presented in percentage or proportion. The misses/omissions are considered when participants do not respond to each stimulus within the time window. Their percentages are complementary to the percentage of correct responses and errors: [% of misses = % total of stimuli – (% of correct responses committed + % of errors committed)].

Steele et al., 2013; Woods et al., 2015). In computerized go/no-go paradigms, it is common to consider several behavioral measures, such as: hits, misses/omissions, false alarms, correct rejections, and reaction times. Hits correspond to the *go* stimuli (target) that are followed by the predefined button press, whereas misses/omissions[2] refer to the number of times a participant failed to press the specific keyboard key in the presence of the *go* stimuli. False alarms correspond to the cases in which the participant presses the keyboard key to the *no-go* stimuli (non-target). Correct rejections[3] correspond to the trials in which the participants do not respond to the *no-go* stimuli. Reaction times refer to the time between the onset of the imperative stimulus and the registration of the keyboard key press; they usually refer to the correct responses only. All measures are registered within a specific time window; responses given outside this time window are considered misses/omissions (e.g., Rodrigues & Pandeirada, 2015; Steele et al., 2013).

Working memory refers to a system (or set of sub-systems) with a limited capacity that is responsible for the temporary manipulation and storage of information (Baddeley, 1992, 2010, 2012). One of the most explored working memory models is the one proposed by Baddeley and Hitch (1974), which has been updated over the years (e.g., Baddeley, 1992, 2001, 2010, 2012), and experimentally replicated by several authors (e.g., Santana & Galera, 2014). This working memory model suggests that there are four main components: central executive, visuo-spatial sketch-pad, phonological loop, and episodic buffer. The first component is responsible for the attentional focus, that is, allow us to select essential stimuli for a given task and to ignore irrelevant information/distractors. The visuo-spatial sketch-pad manipulates and storages spatial and visual information, whereas the phonological loop is responsible for the manipulation and storage of verbal material. The episodic buffer integrates verbal and visuo-spatial information; it is also essential to connect recent information with the long-term memory system (Baddeley, 2010, 2012). This model is one of the most important in explaining cognitive functioning, not only because it is able to explain working memory functioning, but also because researchers have found a bidirectional

[2] The behavioral measures of go/no-go tasks are frequently presented in percentage or proportion. The percentage of misses/omissions is complementary to the percentage of hits: [% of omissions = % total of *go* stimuli - % of hits committed].

[3] The percentage of correct rejections is complementary to the percentage of false alarms: [% of correct rejections = % total of *no-go* stimuli - % of false alarms committed].

relation between working memory and several other cognitive processes, such as selective attention, response selection, and inhibition (Barrett et al., 2016; Gaspar et al., 2016; Gazzaley & Nobre, 2012; Rowe, Toni, Josephs, Frackowiak, & Passingham, 2000). These cognitive processes share a strong relationship (Gazzaley & Nobre, 2012; Konstantinou, Beal, King, & Lavie, 2014). For instance, in a given environment (with several stimuli, particularly visuo-spatial information), selective attention, working memory, and inhibition are three crucial processes as they allow us to select external stimuli (selective attention) according to our internal representations (working memory), and to inhibit responses to non-target stimuli (distractors) (Dube, Basciano, Emrich, & Al-Aidroos, 2016).

The bidirectional relation between selective attention and working memory has been explained by the top-down modulation that is mediated by the prefrontal cortex (Zanto, Rubens, Thangavel, & Gazzaley, 2011), which also plays a crucial role in the relation between selective attention and inhibition. The first is mostly guided by processes in the prefrontal cortex which is regulated by inhibitory signals (Schrobsdorff, Ihrke, Behrendt, Hasselhorn, & Herrmann, 2012). Although a group of brain areas are involved in selective attention, inhibition, and working memory, as we mentioned above, the prefrontal cortex has been identified as having special relevance in these processes (Lara & Wallis, 2015; Rae, Hughes, Anderson, & Rowe, 2015; Squire, Noudoost, Schafer, & Moore, 2013). The prefrontal cortex, a neocortical region that receives and sends projections of several cerebral regions, is very important for the top-down and bottom-up modulations (Katsuki & Constantinidis, 2012; Zanto et al., 2011). That is, in a complex environment, the prefrontal cortex is responsible for controlling the stimulus-driven selection (bottom-up modulation), and guides our behavior according to our internal states and goals (top-down modulation; Eimer, 2014; Miller & Cohen, 2001; Zanto et al., 2011).

Overall, cognitive functions throughout the lifespan describe an inverted U-shaped curve, that is, they develop during childhood, continue to maturate in adolescence, reach their peak in adulthood, and then decline as adulthood progresses to older ages (Craik & Bialystok, 2006; Sander, Lindenberger, & Werkle-Bergner, 2012). The beginning of the cognitive declination is not consensual in the literature. For some researchers, it starts in middle-adulthood, whereas for others it usually starts at older ages (e.g., 60-70 years old; Salthouse, 2009). More consensual is the idea that cognitive functions change across the lifespan, although these alterations follow different paths depending on the cognitive domain (Craik & Bialystok, 2006; Rodrigues, 2012; Sander et al., 2012; Williams, Ponesse, Schachar, Logan, & Tannock, 1999). To understand these developmental differences, it is very common to administer specific cognitive tasks to different age groups and to compare their results (e.g., Brockmole & Logie, 2013; Swanson, 2017; Vidal, Mills, Pang, & Taylor, 2012; Williams et al., 1999). This has been done in the three domains of interest in this work.

Regarding selective attention, we exemplify the response-competition paradigm, a widely used paradigm in selective attention studies, as mentioned above (Lavie, 2005; Lavie et al., 2004; Tan et al., 2015). An example based on this paradigm includes the presentation of a group of letters displayed in a circular array on the computer screen. In each trial, the participant is instructed to indicate (responding with a specific keyboard key) which pre-specified letter (*X* or *N*) is shown in the circular array, whereas a distractor appears in the periphery of the circle. The circular array is composed of distinct letters including one of the two letters: *X* or *N*. The peripheral letter (distractor) is also the letter *X* or *N*. Thus, two types of conditions are usually administered: congruent and incongruent; in the first case, target and distractor are the same letters (e.g., *X*-target and *X*-distractor), while in the incongruent condition the target letter differs from the distractor. This constitutes a selective attention task because the participant has to select the target letter among other letters. In general, performance is worse in incongruent conditions (revealed by fewer correct responses and slower reaction times), because of response-competition, that is, the cognitive resources are divided between different letters. This type of tasks has been applied in different age groups, revealing differences in their results which usually describe an inverted U-shaped curve. In particular, the results of this task have revealed that the performance of children and older people is worse than that of young adults. Such results have led authors to conclude that children and older adults have lower processing capacity than other age groups, specifically than young adults (for a review, see Lavie, 2005). This tendency has been found in several developmental studies with different experimental paradigms (e.g., Combi-TVA task[4]; McAvinue et al., 2012). As mentioned above, vCRTs require not only the selection of information, but also the selection and execution of adequate responses, and also assess processing speed. This type of tasks

[4] This task assessed selective attention and involved a flash of red and blue letters; participants were instructed to report verbally all red letters (targets), ignoring the blue letters (distractors). It was a combination of visual stimuli and verbal responses (combi).

has revealed age differences in their results; for instance, young adults provide usually higher percentage of correct responses and are faster than children and older adults (Dykiert et al., 2012; Woods et al., 2015). This is one of the tasks we adopted in the current project.

Other traditional tests are also used for assessing selective attention, such as the *d2 - test of attention* (Brickenkamp, 2007). This test consists of a paper sheet with 14 rows. Each row contains 47 characters; each character corresponds to one of two letters: *d* or *p*. Each letter contains one, two, three or four traits superscript and/or subscript. Participants are instructed to find the letter *d* in each of the rows that contains two traits (i.e., $\overset{II}{d}$ $\underset{II}{d}$ $\overset{I}{\underset{I}{d}}$). For each row, the participant has 20 seconds to perform the task. In this test, both the targets (letter *d* with two traits) and the distractors (letter *d* with one, three or four traits, and letter *p* with one, two, three or four traits) are presented in the same visual display, that is, in a paper sheet. Results have also revealed an inverted U-shaped curve, in which children and older adults presented the worst performance, followed by adolescents, and finally the young adults that presented the best performance (e.g., Brickenkamp, 2007; Rivera et al., 2017).

In this paragraph, we present conclusions of studies that investigate inhibition in different age groups. Williams et al. (1999) studied response inhibition in a large sample of participants (N = 275) aged between 6 and 81 years. In this research, two letters appeared on the computer screen, one at a time: *X* or *O*. Participants were instructed to press as quickly as possible in the specific response button as the letter appeared (each letter had a specific response button) - this corresponded to a visual choice reaction time task/response selection task. In the second part of the experiment, participants continued to performe the task, but were now instructed to stop responding to trials whenever they heard a tone (stop-signal) – this corresponded to the response inhibition task. In both tasks, the dependent variables were the reaction times (ms). The results revealed an U-shaped curve not only in inhibitory response, but also in the choice reaction time task. In other words, the ability to select stimuli and to inhibit responses improved throughout childhood and adolescence, and started to decline after adulthood. However, the authors claimed that “the age-related change in inhibitory control could not be explained by general speeding or slowing of responses” (Williams et al., 1999, p. 205). In another study conducted by Kim, Iwaki, Imashioya, Uno, and Fujita (2007), a visual go/no-go task was administered to compare the performance of children (N = 9; M_{age} = 8.90

years) with that obtained by young adults (N = 13; M_{age} = 23.32 years). In this task, several equilateral triangles were presented one at a time in four different positions on a computer screen. The experience was composed of 240 trials divided into 12 blocks with 20 trials each. In each block, the majority of the triangles (60%) appeared in a vertical position and pointing up, whereas 20% appeared in a vertical position and pointing down; in the remaining trails (20%), triangles were shown in other positions. Participants were instructed to press a specific keyboard key when the stimulus was a triangle pointing up (*go* stimulus) and not to press the keyboard key when triangles pointing to other directions were presented (*no-go* stimuli). The results suggested that, although there were no significant age group differences in error rates, the reaction times were statistically different between the young adults and children, with young adults being significantly faster at responding (i.e., shorter reaction times) than children.

Regarding the visuo-spatial memory, we focus on the Rey Complex Figure. This is one of the most widely used visuo-spatial tasks in the world, and it assesses several cognitive processes, such as visuo-spatial abilities (e.g., visuo-spatial memory), as well as planning, organizational, perceptual, motor, and constructive skills (Rey, 1988). This task can be administered in many forms of which we highlight two: copy and immediate recall. In the copy administration, participants are instructed to copy the Rey Complex Figure in the presence of the stimulus-figure. In the immediate recall, which occurs three minutes after concluding the copy, participants are instructed to reproduce the same figure without the presence of the stimulus-figure. In both cases, the maximum score is 36 points. This test has been applied in several age groups, including children and adolescents (Fernando, Chard, Butcher, & McKay, 2003), as well as in young- and older adults (Yamashita, 2015). Similarly to the attentional and inhibition tasks described above, the Rey Complex Figure has been sensible to detect developmental differences. Specifically, in immediate recall, Simões, Pinho, Lopes, Sousa, and Lopes (2011) reported that performance increased with age in a sample composed of participants aged 5-15 years. Bonifácio, Cardoso-Pereira, and Pires (2003) conducted a research with 145 participants aged 15-90 years divided in three groups: 15-39, 40-59, and ≥60 years old. The authors found that the first group obtained the best performance, followed by the second group, and finally the older participants who obtained the worst immediate recall.

Another task that is widely administered in different age groups is the Corsi block-tapping task (Corsi, 1972; Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2010;

Pagulayan, Busch, Medina, Bartok, & Krikorian, 2006). This task has been used to assess visuo-spatial working memory in clinical and non-clinical samples, as well as in a wide variety of research settings (Brunetti, Del Gatto, & Delogu, 2014; Kessels, van den Berg, Ruis, & Brands, 2008). The traditional task consists of a board with nine numbered cubes (1-9). Individuals are instructed to reproduce block-tapping sequences of increasing length (more detailed information is provided in the General Method of this work). Besides this traditional form of administration, computer versions have also been used in several samples and contexts (e.g., Mueller & Piper, 2014; Robinson & Brewer, 2016). Age differences have also been revealed in this task (e.g., Brunetti et al., 2014; Pagulayan et al., 2006), corroborating the cognitive developmental pattern previously described. For example, Carlesimo et al. (1998) reported the following age-related differences on the memory span measured by this task: young adults (M_{age} = 29.4 years) performed better than older adults (M_{age} = 66.7 years), who, in turn, obtained a higher memory span than very old adults (M_{age} = 82.5 years). Similar results were obtained in a study in which a eCorsi form (computerized version) was used: young adults (M_{age} = 21.6 years) had higher memory span than older adults (M_{age} = 57.6 years) (Brunetti et al., 2014). Pagulayan et al. (2006) administered the Corsi block-tapping task in a sample aged 7-21 years, and concluded that memory span capacity increased linearly with age. A more recent study by Burggraaf, Frens, Hooge, and van der Geest (2017) revealed a similar pattern of results; in a sample composed of 330 participants aged 11-20 years, they assessed visuo-spatial memory with a task inspired by the Corsi block-tapping task. The authors found that performance improved with age, that is, the number of correctly identified patterns increased with age (with no gender differences).

In short, in our everyday life, our cognitive system allows us to select relevant information from our surrounding environment, while ignoring irrelevant information/distractors. This capacity changes across the lifespan and can be measured by several cognitive tasks as mentioned above. To understand the mechanisms underlying the inhibition of irrelevant information (distractors) is essential in cognitive psychology. In the next topic, we explore in greater detail the study of visual distraction and present a different experimental approach that has been recently created (Rodrigues & Pandeirada, 2015) to explore this issue.

1.2. The study of visual distraction: From a typical to an alternative experimental paradigm

The study of distraction for visuo-spatial information is vast, and it has been conducted with several age groups and different types of tasks (Chadick, Zanto, & Gazzaley, 2014; Gupta, Hur, & Lavie, 2016; Lavie, 2010; Madden & Langley, 2003; McAvinue et al., 2012; Sander et al., 2012; Zanto et al., 2011; Zelazo, Craik, & Booth, 2004). For the most part, these studies use computerized tasks in which target stimuli and distractors are presented on a computer screen, as we referred above (e.g., Lavie, 2010; Madden & Langley, 2003). Many of these tasks are based on the Load Theory of Attention (Lavie et al., 2004), which defends two mechanisms of selective attention. One is a perceptual selection mechanism which comes into action in high-load conditions preventing distractors from affecting current performance. The other is an active attentional control mechanism that is triggered in low-load conditions after distractors have been perceived; this mechanism which depends on several other cognitive functions, such as working memory, allows one to ignore the irrelevant distractors (Lavie, 2005, 2010). This type of tasks, usually in computerized versions, has allowed us to point out practical implications for the daily life of several age groups (Forster & Lavie, 2011; Lavie, 2005, 2010). However, little is known about the selective capacity of individuals in contexts that more closely mimic real life as stressed by several authors (e.g., Lavie, 2010; Wu, Wick, & Pomplun, 2014).

A different vein of studies has explored how the visuo-spatial characteristics of the surrounding environment impact several aspects of human routines, such as in healthcare settings, in workplaces, forensic area, driving performance, or scholar contexts, just to name a few examples. Next, we present some studies which show the importance of the research on the interaction between environment and human performance.

In clinical settings, the presence of certain elements (e.g., nature paintings, live plants, television) seems to produce a positive effect on patient satisfaction, emotional states and speed of recovery, as compared to control rooms without these elements (Devlin & Andrade, 2017). In such settings, the influence of the surrounding environment on several variables, such as stress (Andrade & Devlin, 2015; Ulrich, Simons, & Miles, 2003), patient anxiety and agitation (Aghaie et al., 2014; Nanda, Eisen, Zadeh, & Owen, 2011), pain control (Diette, Lechtzin, Haponik, Devrotes, &

Rubin, 2003; Vincent, Battisto, Grimes, & McCubbin, 2010), and subjective well-being (Raanaas, Patil, & Hartig, 2010; Tanja-Dijkstra, 2011), has been widely explored.

Ecological approaches have also been considered in organizational settings over the last decades (Davis, 1984; Kwallek, Soon, Woodson, & Alexander, 2005; Thayer et al., 2010). The effect of color walls in job satisfaction and in perceived performance are two of the most studied aspects. For instance, Kwallek et al. (2005) conducted a study in which the participants were separated into three different groups; this distribution took into account the participants' capacity to ignore irrelevant stimuli as measured by a previous screening. Each group performed a set of office tasks throughout four days, but one of them performed the tasks in an office painted in white, other group in a red office, and the third group performed the tasks in a blue-green office. The three spaces were identically furnished and had a similar size. The results suggested that higher perceived job satisfaction and perceived performance were found in the white and in blue-green offices, when compared to the red office. Additionally, the participants with a higher or moderate capacity to ignore irrelevant stimuli revealed greater job satisfaction and performance than the participants with low capacity. Other aspects have been studied in workplaces contexts, such as the effect of the surrounding environment in physiological stress response (e.g., Thayer et al., 2010), or in employee's productivity (Barry, 2008a, 2008b).

The influence of the surrounding environment has also been considered is the forensic area. In a study conducted by Mastroberardino and Vredeveldt (2014), a sample of 120 children aged 8-11 years participated in a stimulated eyewitness interview. Children were tested individually in an isolated room at their school. Each participant watched a short clip showing a series of events taking place in a residence (e.g., an individual stealing € 50 from a wallet; a girl making a phone call). Then, a cued-recall interview was conducted in four distinct conditions: black screen, eye-closure, visual distraction, and auditory distraction conditions. The participants were divided into four groups, and each one participated in only one of these conditions. In the first, each participant was looking at the black screen while the interview was being conducted. In the eye-closure condition, the participants were instructed to respond to the interview with their eyes closed. In the visual distraction condition, the participants were instructed to look at the screen where visual stimuli appeared. Finally, in the auditory condition, the participants were looking at the black screen while they heard auditory stimuli. Children in the eye-closure and in the black screen conditions provided significantly more correct and fewer incorrect responses about visual details than children in the visual- and auditory-distraction conditions. However, regarding auditory details, the authors did not find differences among the four conditions. The researchers argued that in the two conditions in which the participants had a better performance (black screen and eye-closure), the interference of environmental distractions was minimized. A comparable pattern of results was previously observed in a similar experimental work with an adult sample (Vredeveldt, Hitch, & Baddeley, 2011).

Another applied context in which visual distraction is widely studied refers to driving, particularly in older adults (e.g., Aksan et al., 2013; Cuenen et al., 2015; Salvia et al., 2016). For instance, a study conducted by Aksan et al. (2013) used a naturalistic distraction paradigm (visual search for roadside targets). In this study, 120 healthy older adults and 83 middle-aged drivers participated in an on-road test with an instrumented vehicle. They were instructed to drive to a specific place with a researcher in the front passenger seat. Among other tasks, the participants were instructed to verbally identify traffic signals. Video recordings were also done, and then examined by a certified driving instructor. Results suggested that the older adults identified fewer landmarks and performed more safety errors (e.g., incomplete stops, poor lane observance) than middle-aged participants. Moreover, the authors claimed that it is imperative to create conditions "of implementing and quantifying performance in specific driving tasks typically tested in simulator studies, in the real-world" (p. 848).

The characteristics of the surrounding environment in school settings have also received interest in recent years with a focus on how it impacts learning (Fisher, Godwin, & Seltman, 2014; Godwin et al., 2016). A theoretical approach that has been used to explain the influence of the surrounding environment in learning gains is the environment-behavior model (Barrett, Davies, Zhang, & Barrett, 2015, 2016). According to this model, children's achievement can be affected by the physical environment of classrooms. This model supports three design principles that can impact learning gains: naturalness, individualization, and stimulation. The first considers that "links to nature" (Barrett et al., 2015, p. 119; e.g., daylight and plants) are essential to provide adequate space for learning. The individualization principle defends that intimate and personalized spaces are better for learning activities. The stimulation includes two parameters which are very important in classrooms: complexity and color of the space (Fisher et al., 2014; Godwin et al., 2016; Jalil, Yunus, & Said, 2012). Specifically, the colors of spaces have an impact in learning activities not only in younger students (Barrett et al., 2015), but also in college students (Al-Ayash, Kane, Smith, & Green-Armytage, 2016). For instance, vivid blue helps to focus attention on learning activities, whereas vivid red and yellow are associated with distraction and impairment of attention (for a review, see Al-Ayash et al., 2016). The complexity of the environment includes elements of the room (e.g., visual elements) and how they are combined to create a structured or a chaotic surrounding environment (Barrett et al., 2015). The latter has inspired a series of studies, such as the following two: (1) Fisher et al. (2014) and (2) Stern-Ellran, Zilcha-Mano, Sebba, and Levit Binnun (2016).

The study by Fisher et al. (2014) aimed to study if the presence (absence) of visual elements in children's learning environment would affect their learning gains. To this end, in a within-subjects design, twenty-four children (M_{age} = 5.37 years) participated in several lessons over two weeks. Half of the lessons occurred in a decorated-classroom and the remaining in a sparse-classroom. The decorated-condition was a laboratory classroom containing several visual elements usually found in schools, such as posters, maps, and paintings, whereas the sparse-classroom was a laboratory room without these visual stimuli (illustration of the two environmental conditions: Fisher et al., 2014, p. 1364). The order of the environmental manipulation was alternated among lessons, with the first occurring always in the sparse-classroom. After each lesson, paper-and-pencil assessments were applied to measure learning gains. All lessons were videotaped to register children's behavior, including their distractibility. Four coders classified the participants' behaviors during lessons as on- or off-task according to the direction of the children's eye gaze. When children were engaged with a teacher or with other learning elements (e.g., books), their behaviors were classified as on-tasks, whereas when they were interested in irrelevant information (engagement with surrounding environment or with another child), behaviors were classified as off-tasks. Moreover, the duration of each off-task behavior (distraction) was also measured. Distractions were classified into four types: self-distraction, peer distraction, environmental distraction, and other distractions. Results suggested that the high-decorated environment impaired learning gains. Participants were also more distracted and spent more time off-task in the decorated-classroom, as compared to the sparse-classroom. Additionally, in the decorated-classroom condition, the central source of distraction was the surrounding environment (i.e., maps, drawings, pictures, etc.). This work stressed the potential negative effect of a high-decorated classroom in children's performance. In a review paper by Choi, van Merriënboer, and Paas (2014), the authors claim that researchers have "paid very little attention to the effects of the physical learning environment on cognitive load and learning" (p. 238); this is a topic that has been overlooked in the psychology literature.

A study by Stern-Ellran et al. (2016) aimed to identify the effect of a colorful *vs*. non-colorful surface on children's structured play. To this end, preschool children (age range: 38-52 months) performed three typical preschool games in a colorful and in a non-colorful surface in two separate sessions. In the colorful condition, a surface was covered with paper containing several images and colors, whereas in the non-colorful condition the stand was covered with a white paper. Each child, individually (only in the presence of the researcher), completed two sessions with an interval of 1-2 weeks between them. One of the sessions was performed in the colorful and the other in the non-colorful condition. The order of the conditions was randomized across participants, and the order of the games was the same for all participants and in the two sessions. Similarly to Fisher et al. (2014), each session was recorded by two cameras that allowed researchers to code and analyze children's behavior. According to the results, in the colorful surface, children had more disruptive behaviors than in the non-colorful surface. The disruptive behaviors included, for instance: looking away, vocalizing, and missing pieces of the game. The authors argued that children were more distracted in the colorful than in the non-colorful surface and speculated that these results could be due to an influence of the visual surrounding environment in attentional, perceptual, and other cognitive processes, as well as to immaturity of the voluntary control of attention. Of note, although it is proposed that basic cognitive processes could explain the findings, this study did not use specific cognitive tasks.

The last couple of studies discussed their results assuming that the environment caused a worsening in learning and play performance, two more "complex" dependent variables. However, studies exploring the relation between the visual surrounding environment and cognitive performance as measured by specific cognitive tasks are scarce. An exception is our previous study conducted with a sample of older adults (Rodrigues & Pandeirada, 2015). In this study we aimed to explore the influence of the surrounding environment in specific cognitive tasks that evaluated visual attention, inhibition, and verbal working memory in older adults (N = 40; M_{age} = 72.98 years). In a within-subject design study, forty older adults performed two visual attention tasks (simple reaction time and go/no-go tasks), and three verbal working memory tasks (arithmetic, memory for digits and sequences of letters and numbers) in two sessions separated by an interval of 14–21 days. Importantly, in one of these sessions, tasks were performed in a high-load visual surrounding environment (a room displaying several visual stimuli, such as posters and photos), and in the other in a low-load visual surrounding environment (the same room without visual elements in the wall). For an illustration of the two environmental conditions, see Figure 1 of the manuscript by Rodrigues and Pandeirada (2015, p. 102). In each session, besides responding to the cognitive tasks mentioned above, participants responded to a couple of additional questionnaires; these provided information about additional variables (e.g., age, sex, general cognitive level). The order of the environmental manipulation and of the tasks were counterbalanced across participants. The results revealed that cognitive performance in the attentional tasks was impaired when these were performed in the high-load visual environment. Specifically, when the session was conducted in the high-load condition, participants provided fewer accurate responses, more false alarms and higher reaction times to the correct responses in the go/no-go task. In both visual attention tasks, the number of omissions was also higher in the high-load environment. As for the memory tasks, only performance in the memory for digits in a forward direction differed between conditions, being worse in the high-load condition than in the low-load. We proposed that the effect of the visual surrounding environment had no influence on the remaining tasks because they were not mainly focused on visual stimuli; for example, the distractors were visual and the memory relied on the oral/auditory modalities. In this work, we combined validated cognitive tasks with a visual surrounding manipulation, providing a more ecological procedure. A particularity of our previous work (Rodrigues & Pandeirada, 2015) can be highlighted in relation to the studies previously mentioned (Fisher et al., 2014; Stern-Ellran et al., 2016): we used basic cognitive tasks that underlie more elaborated cognitive processes (e.g., learning). Thus, we believe that the experimental paradigm used in our last study allows us to better understand how basic cognitive processes (that underlie more complex behaviors) are influenced by the surrounding environment and will, ultimately, allows to better comprehend human behavior in various settings (e.g., in scholar or organizational settings).

Individuals are continually inserted in a visual surrounding environment which frequently appears to them as a "visual bombardment" (Bullard, 2016, p. 110), for example: children and adolescents in schools, adults in workplaces, and older adults in daycare centers. As mentioned earlier, it is impossible to process all the stimuli that surround us because our cognitive capacity is limited. Additionally, the capacity to do so changes across different developmental stages. As mentioned above, Rodrigues and Pandeirada (2015) presented an exploratory study in which they proposed an alternative experimental paradigm that connects validated cognitive tasks with a more ecological approach. The present study aimed to further explore this procedure by examining the effect of visual surrounding elements in cognitive performance (assessed by specific cognitive tasks) in different developmental stages: children, adolescents, young adults, and older adults. Additionally, we provide preliminary data of the environmental influence in cognitive achievements taking into account several variables known to affect cognitive performance, as considered next.

1.3. Anxiety, depression, and chronotype: What are their roles in cognitive performance?

In cognitive psychology studies, several individual variables are usually considered, such as anxiety, depression, and chronotype, as they have shown to influence cognitive performance (Castaneda, Tuulio-Henriksson, Marttunen, Suvisaari, & Lönnqvist, 2008; Fabbri, Frisoni, Martoni, Tonetti, & Natale, 2017; Schmidt, Collette, Cajochen, & Peigneux, 2007).

Anxiety is a natural emotion with adaptive functions that prepares the individual to cope with the environment. It usually includes cognitive, physiological, and behavioral manifestations (Gutiérrez-García & Contreras, 2013; Hendriks, 2017; MacLeod & Mathews, 2012). In anxious individuals, the environmental stimuli are filtered in agreement with previous experiences (Gutiérrez-García & Contreras, 2013). Nevertheless, when anxiety is excessive, it can become distracting, disruptive, and incapacitating (MacLeod & Mathews, 2012; Vytal, Cornwell, Letkiewicz, Arkin, & Grillon, 2013).

One of the best-known models of anxiety is the State-Trait Anxiety Theory proposed by Spielberger, Gorsuch, and Lushene (1970). According to this model, there are two different types of anxiety: state- and trait-anxiety. The first refers to a transitory emotional reaction to a real or potential stressful stimulus (momentary), while the trait-anxiety refers to a relatively stable tendency (predisposition) to experience anxiety. As mentioned above, anxiety can disrupt cognitive performance, particularly the state-anxiety (e.g., Derakshan, Smyth, & Eysenck, 2009; Hadwin, Brogan, & Stevenson, 2005; Shackman et al., 2006; Wetherell, Reynolds, Gatz, & Pedersen, 2002). Its negative effect in cognitive domains is very well documented, including in visuo-spatial cognitive processes, in which anxious people have a tendency for higher distraction (e.g., Lapointe et al., 2013; in this study, participants were instructed to remember sequences of visuo-spatial targets sometimes presented within irrelevant information). The negative influence of higher anxiety in cognitive processes is usually explained by the Attentional Control Theory (Eysenck, Derakshan, Santos, & Calvo, 2007). According to this theory, anxiety biases several cognitive processes, including cognitive control, because anxious individuals prioritize bottom-up over top-down attentional processes, leading to competition of limited resources in working memory, particularly the central executive. In other words, anxiety occupies attentional resources that otherwise would be used to respond to a given task. In most studies, anxiety has been assessed by self-report questionnaires, particularly by Spielberger's scales (Spielberger, Edwards, Lushene, Monturoi, & Platzek, 1973; Spielberger et al., 1970). Although trait-anxiety can be measured, it is common to measure state-anxiety, that is, the degree of anxiety that participants are feeling at the exact moment they are responding to the scale (e.g., Derakshan et al., 2009). This variable has shown a negative effect on cognitive performance in several age groups (e.g., young adults: Derakshan et al., 2009; children: Hadwin et al., 2005; older adults: Stillman, Rowe, Arndt, & Moser, 2012), although inverse results also exist (e.g., Ursache & Raver, 2014). However, an optimal point of anxiety seems to be necessary to obtain a peak of cognitive performance (Stillman et al., 2012). Independently of these non-consensual results, state-anxiety is an important variable to consider in studies, as mentioned before.

Depression also seems to be negatively associated with cognitive performance, such as with psychomotor speed, attention, learning, visual memory, and executive functions (Castaneda et al., 2008; Holt et al., 2016; Kizilbash, Vanderploeg, & Curtiss, 2002). Depressed individuals tend to have a lower ability to supress irrelevant information, as well as slower reaction times as compared with non-depressed individuals (Desseilles et al., 2009; Levin, Heller, Mohanty, Herrington, & Miller, 2007). The impairment of cognitive functions in individuals with higher scores of depression (which is usually measured with depression questionnaires) has been found in several age groups, specifically in children (working memory and depression; Aronen, Vuontela, Steenari, Salmi, & Carlson, 2005), adolescents (cognitive control and depression; Vijayakumar, Whittle, et al., 2016), young adults (neuropsychological functioning and depression; Baune, Fuhr, Air, & Hering, 2014), and older adults (executive functions and depression; Lockwood, Alexopoulos, & van Gorp, 2002). Several explanations have emerged to explain cognitive impairments in depressed individuals: (1) these individuals tend to need a greater degree of certainty before they respond, a phenomenon named as catastrophic response failure; (2) they usually have reduced motivation to respond to specific stimuli in cognitive tasks; (3) they also present mood-related attentional and memory biases in information processing; (4) in some cases, abnormalities in limbic-thalamic-cortical circuits, which are a part of the neurophysiology of depression, lead to detrimental executive functions (Austin, Mitchell, & Goodwin, 2001; Porter, Bourke, & Gallagher, 2007). The recognized importance of depression to cognitive performance (e.g., Scult et al., 2016) justifies its consideration in our research.

Another important variable that influences cognitive performance is chronotype or morningness-eveningness preferences (Dorrian, McLean, Banks, & Loetscher, 2017; Preckel, Lipnevich, Schneider, & Roberts, 2011; Schmidt et al., 2007). Chronotype is an individual characteristic based on the sleep-wake cycle mirrored in daily fluctuations in psychological and physical abilities (López-Samanes et al., 2016; Matchock & Mordkoff, 2009; Schmidt et al., 2007). There are three main types of chronotype to classify individuals: morning-, intermediate-, and evening-type. In the first type, individuals have peaks of performance in the morning, in the second in the middle of the day, and evening-types have their peaks of performance in late hours of the day. In developmental terms, children tend to be morning-types and become progressively evening-types during adolescence; the peak of eveningness usually occurs around the age of 20. After that, individuals shift progressively to a morning preference (Randler, Faßl, & Kalb, 2017; Roenneberg et al., 2004).

Several studies have revealed an influence of the chronotype in several cognitive areas, such as attention, executive functions (e.g., inhibition), and working memory (Valdez, 2012; Valdez, Ramírez, & García, 2014). In general, the peak of performance is closely correlated to biological factors, such as body temperature which reach its peak in different hours of the day according to specific chronotypes (Fabbri et al., 2017; Hahn et al., 2012; Schmidt et al., 2007). Studies have also revealed that when tasks are performed during a person’s chronotype optimal period (e.g., an evening-type person performs the task at later times of the day), performance is better than when they are done outside of the person's optimal period (e.g., an evening-type person performing the task at earlier times of the day). In the first case, we say the task is being performed in a synchrony moment, and in the second in an asynchrony moment. Due to the potential effect of synchrony/asynchrony in cognitive performance, in research that includes multiple sessions with the same participant, it is important that these occur during the same period of day (Schmidt et al., 2007). Self-report questionnaires have been one of the most used methods to assess chronotype in different contexts and with different age groups, although other several methods exist, such as body temperature and activity measurement, and onset melatonin secretion (for an overview of alternative methods, see: Valdez, 2012).

Considering the potential relevance of state-anxiety, depression, and chronotype to cognitive performance, we included their assessment across all of our groups using validated self-report measures. Because these are only secondary to the main aims of our study, we only explore their potential influence in our results in a final chapter of this work.

1.4. Aims

The overall aim of this study was to explore the influence of a high-load *vs.* a low-load visual surrounding environment in visuo-spatial cognitive performance as measured by specific cognitive tasks. In a mixed design, different age groups of participants participated in two sessions with an interval ranging between 14 and 23 days. One session was performed in a high-load visual surrounding environment, whereas the other in a low-load visual surrounding environment. In each session, four visuo-spatial cognitive tasks were performed by each participant. Additional instruments to assess individual variables were administered.

The specific aims of this work were:

1. To study the influence of a high- *vs.* a low-load visual surrounding environment in four cognitive tasks (visual choice reaction time, go/no-go, Corsi block-tapping, and Rey Complex Figure[5]) in four distinct age groups: children, adolescents, young adults, and older adults. We expected that cognitive performance would be damaged when tasks were performed in the high-load as compared to the low-load surrounding environment (Chapters 3-6).
2. To explore if the predicted environmental influence on these cognitive tasks interacts with age group. Considering the typical inverted U-shaped relation between age and cognitive performance, we expected that the high-load visual surrounding environment would be more disruptive in the cognitive performance of children, adolescents, and older adults, as compared to the young adults who are in their peak of cognitive abilities. Such result was expected in children and adolescents, because both groups are still undergoing cognitive maturation, which includes the development of the capacity to ignore distractors (Chapters 3, 4, and 6); in older adults, because this age group shows typical cognitive declines (Chapters 5 and 6).
3. To explore the relation between the cognitive performance obtained in the two environmental conditions and: (i) state-anxiety, (ii) depression, and (iii) chronotype. These results are presented as exploratory only, given that we did not manipulate these variables. We anticipated that the influence of the high-load visual environment would be larger in the participants with depression and anxiety, given that they are more susceptible to distraction. Regarding chronotype, we expected that participants who performed the tasks in their non-optimal period would be more affected by the high-load visual environment than participants who completed the experimental sessions in their optimal period (Chapter 7).
4. To present possible practical implications in light of our findings and suggestions for future studies (Chapter 8).

[5] Visual choice reaction time and go/no-go tasks are two of the most applied tasks to assess selective attention, response selection and processing speed, and inhibition, respectively. The Corsi block-tapping and the Rey Complex Figure correspond to two tasks widely used to assess visuo-spatial working memory (although the last also assesses other cognitive processes). These four cognitive tasks have been used in cross-sectional studies showing sensitivity to detect developmental differences. Detailed information of each task is provided in Chapter 2 (General Method).

CHAPTER 2.

General Method

Published work related to this chapter:

Rodrigues, P. F. S., Pandeirada, J. N. S., Bem-Haja, P., & França, J. (in press). Assessing state-anxiety in European Portuguese children and adolescents: Adaptation and validation of the State Anxiety Scale for Children. *Measurement and Evaluation in Counseling and Development*.

Rodrigues, P. F. S., Pandeirada, J. N. S., Bem-Haja, P., & França, J. (2017). The Trait Anxiety Scale for Children: A validation study for European Portuguese children and adolescents. *European Journal of Developmental Psychology*, 1-9. doi: 10.1080/17405629.2017.1308249

Rodrigues, P. F. S., Pandeirada, J. N. S., Marinho, P. I., Bem-Haja, P., Silva, C. F., Ribeiro, L., & Fernandes, N. L. (2016). Morningness-eveningness preferences in Portuguese adolescents: Adaptation and psychometric validity of the H&O questionnaire. *Personality and Individual Differences, 88*, 62-65. doi: 10.1016/j.paid.2015.08.048

Oral presentations related to this chapter:

Rodrigues, P. F. S., & Pandeirada, J. N. S. (2016). *Influência do ambiente visual circundante no desempenho cognitivo: um novo procedimento de investigação [Influence of the visual surrounding environment in cognitive performance: A new research procedure]*. Oral communication presented at the 3rd Congress of the Portuguese Order of Psychologists, Porto, Portugal.

Rodrigues, P. F. S., & Pandeirada, J. N. S. (2015). *Adaptação e validação do "State-Trait Anxiety for Children" em crianças e adolescentes portugueses [Adaptation and validation of the "State-Trait Anxiety for Children" in Portuguese children and adolescents]*. Oral communication presented at the Colóquio de Educação Especial "Formar para Incluir, Inovando" [Colloquium of Special Education "To educate for inclusion, innovating"], Estarreja, Portugal.

Rodrigues, P. F. S., & Pandeirada, J. N. S. (2014). *Atenção seletiva, inibição e memória de trabalho: A influência de ambientes distrativos [Selective attention, inhibition, and working memory: The influence of distracting environments]*. Oral communication presented at the Cycle of Conferences Under Investigation: Psychology@UA (2nd edition), University of Aveiro, Portugal.

Poster presentations related to this chapter:

Rodrigues, P. F. S., Marinho, P. I., Ribeiro, L., Pandeirada, J. N. S., Silva, C. F., Fernandes, N. L., & Bem-Haja, P. (2015). *Tradução e adaptação do questionário de Horne & Östberg numa população de adolescentes portugueses [Translation and adaptation of the H&Ö Questionnaire to Portuguese adolescents]*. Poster presented at the 10th National Meeting of the Portuguese Association of Experimental Psychology, Faro, Portugal.

2.1. Brief introduction

In this section, we describe global aspects of the Methodology used in the studies included in this project. Specific details about each age group are provided in the Chapters reporting the results of each age group: children (Chapter 3), adolescents (Chapter 4), and young adults and older adults (Chapter 5). We begin by describing the participants, identifying the instruments, and describing the elaboration of the two environmental conditions (high-load and low-load visual environments). This section ends with a description of the global procedures administered in all studies of this project.

The developmental dimension of this research was considered in the selection and/or adaptation of the cognitive tasks and instruments that were administered. Specifically, the two attentional tasks were created following several procedures in different age groups, and the chosen memory tasks are widely used in such studies. Regarding the instruments used to assess individual characteristics, we aimed to adopt tools that are already validated for the Portuguese population. Whenever possible, we used a single instrument or similar instruments (with the same conceptual framework) to assess each individual variable across the different age groups. This procedure allowed us to assure the greatest possible consistency among them. To the best of our knowledge, instruments to assess state-anxiety in children/adolescents (8-14 YO) and chronotype in adolescents (12-14 YO) did not formally exist for the Portuguese population; thus, we conducted two exploratory validation studies of the *State-Trait Anxiety Scale for Children* (Appendices 1 and 2) and of the *Morningness-Eveningness Questionnaire* (Appendix 3) for these age groups. Formal authorizations from authors and/or publishers (copyrights' owners) were obtained for all instruments used in this thesis. A couple of informal instruments were created by our research team, specifically the *Visual Screening and Stimuli Recognition* and the *Sociodemographic Questionnaire.*

2.2. Participants

The final sample was composed of 256 participants, which included children, adolescents, young adults, and older adults. Each age group comprised 64 participants, selected by convenience. The children aged 8-12 years (32 females; M_{age} = 10.16, *SD* =

1.36) and the adolescents aged 13-17 years (33 females; M_{age} = 14.44, SD = 1.36); participants of both groups were recruited from two groups of schools of the Aveiro district (Portugal). This study was authorized by the Portuguese Directorate-General for Education (authorization# 0296300010) and by the Directors of the selected schools. The young adults aged 18-29 years (49 females; M_{age} = 21.53, SD = 3.21) and were mostly students attending the University of Aveiro. The older adults aged 65-94 years (40 females; M_{age} = 79.75, SD = 8.06) and were recruited from five daycare centers from the Aveiro district, after obtaining authorization from the directors of these institutions. Moreover, the studies here reported have been approved by the Ethics and Deontology Council of the University of Aveiro (Ethical Approval# 10/2016).

The following exclusion criteria were applied to all age groups: a) to be unable to recognize the stimuli in the *Visual Screening and Stimuli Recognition* tasks; b) to have a clinical score in the *Vocabulary* and/or *Blocks-design* subtests of the *Wechsler Scales* (Wechsler, 2003, 2008); c) to have a history of neurological, psychological, and/or a learning disorder; d) to be illiterate; and, e) to perform the second session outside the predefined time window (14-23 days). One additional exclusion criterion was used in the participants aged $\geq$ 25 years: to obtain a score in the *Mini-Mental State Examination* (MMSE) indicative of clinical condition (according to cut-offs by Freitas, Simões, Alves, & Santana, 2015). Participants with at least one of these criteria were excluded of the reported data. Information regarding a history of neurological, psychological or learning problems and about illiteracy was obtained through the *Sociodemographic Questionnaire*. Further confirmation was obtained by the legal guardians in the case of the children and adolescents, and by the daycare centers' technicians in the case of the older adults.

Three older adults were not included because they presented a clinical score in the MMSE, and another was excluded because she/he failed to identify at least one stimulus in the initial visual screening. Data of one child were also excluded because she/he performed the second session outside the predefined time interval (14-23 days; detailed information in the Procedure of this section).

Informed written consent was obtained for each participant before starting the research sessions. In the case of children and adolescents, a previous written consent was provided by their legal guardians. After completing the two study sessions, all participants were offered a small gift (a backpack or a book) for their collaboration.

2.3. Materials

Cognitive tasks. In each of the two sessions, each participant performed four cognitive tasks: two visuo-spatial attention and two visuo-spatial memory tasks. The attentional tasks corresponded to the *go/no-go* and *choice reaction time* tasks, and were programmed and ran using the software E-Prime 2.0 (Schneider, Eschman, & Zuccolotto, 2002). These tasks followed typical procedures in this area and took into account the different age groups included in this project (e.g., Kawashima et al., 1996; Morooka et al., 2012; Rodrigues & Pandeirada, 2015; Steele et al., 2013; Woods et al., 2015). For example, the choices of the stimuli, of the inter-stimuli intervals, and of the time window for participants to provide their responses were three aspects that were considered. In other words, we ensured that the parameters adopted in the cognitive tasks would allow all age groups to perform each task with success. The memory tasks were the *Corsi block-tapping* and the *Rey Complex Figure*, which are usually administered in developmental studies (e.g., Pagulayan et al., 2006; Rivera et al., 2015; Simões et al., 2011; Yamashita, 2015). We used the computerized version of the Corsi block-tapping available in the free software *PEBL: The Psychology Experimental Building Language* (Mueller, 2012), and the traditional paper-and-pencil format of the Rey Complex Figure (Rey, 1988). The three computerized tasks (go/no-go, choice reaction time and Corsi block-tapping) were performed on a 14’’ screen laptop. The keyboard keys used to respond in each task were “adapted” for easier identification and response by all participants (see details below in the description of each task). Importantly, the computerized tasks did not require specific knowledge or familiarity with computers nor a specific educational level. Furthermore, for each computerized task, each participant performed a training period for familiarization with the task and had the opportunity to clarify any doubts with the researcher. This procedure was conducted at the beginning of each task in each session. Next, we present a detailed description of each cognitive task.

Go/no-go task. This experimental paradigm is widely used to assess inhibition and error processing/error-monitoring (Steele et al., 2013; Steele et al., 2014; Vidal et al., 2012). In this task, targets (*go* stimuli) and distractors (*no-go* stimuli) are usually presented on a computer screen. The *go* stimuli require a specific response and the *no-go* do not require a response (e.g., Steele et al., 2013). This task involves “the ability to monitor conflicts, process response errors, withhold or inhibit a pre-potent response, and learn from response errors" (Steele et al., 2014, p. 127), particularly when the *go* stimuli are more frequent than the *no-go* stimuli.

Following typical procedures in the area (e.g., Kiehl, Liddle, & Hopfinger, 2000; Steele et al., 2013; Steele et al., 2014), one of two letters was randomly and singly presented on the computer screen: *X* or *K*. Each letter was preceded by a 500 ms fixation cross, and then it was presented for a maximum period of 600 ms; this was the maximum time allowed for participants to provide their responses. The background of the computer screen was white and the stimuli were in black color. The inter-trial interval duration was randomly determined from among one of the durations of 500, 1000, 1500 or 2000 ms, to prevent response anticipation. Participants were instructed to press, as soon as possible and accurately, the "white" keyboard key when the *X* appeared on the computer (*go* stimulus) and not to respond when the *K* letter was presented (*no-go* stimulus). A white sticker was placed on the "space" bar of the computer keyboard; this corresponded to the "white" keyboard key. The *go* stimulus (*X*) was presented in 66% of the trials, whereas the *no-go* (*K*) appeared in the remaining 34% of the trials (percentages of *go* and *no-go* trials similarly to those employed by Vara, Pang, Vidal, Anagnostou, & Taylor, 2014; and Vidal et al., 2012). After 12 initial training trials, 140 experimental trials were presented for each participant in each session. A schematic illustration of the task is shown in Figure 1. Similarly to previous studies (e.g., Rodrigues & Pandeirada, 2015; Steele et al., 2013), the behavioral measures (dependent variables) in this task were: hits, false alarms, and reaction times. A hit occurred when the participant pressed the predefined keyboard key (space bar) in the presence of the *go* stimulus (i.e., the letter *X*). A false alarm happened whenever the participant provided a response upon the presentation of the *no-go* stimulus (i.e., the letter *K*). Reaction times corresponded to the time (ms) between the onset of the stimulus and the participant's hit. A couple of other variables could be considered: misses/omissions and correct rejections. The first corresponds to the trials in which participants did not press the predefined keyboard key in the presence of *go* stimuli. Correct rejections are those in which participants did not press the keyboard key in the presence of *no-go* stimuli. Given that misses are complementary results to the hits, and correct rejections are complementary data to the false alarms, their presentation is redundant (as Steele et al., 2013). Therefore, for this task, we reported data regarding the hits, false alarms, and reaction times for the hits.

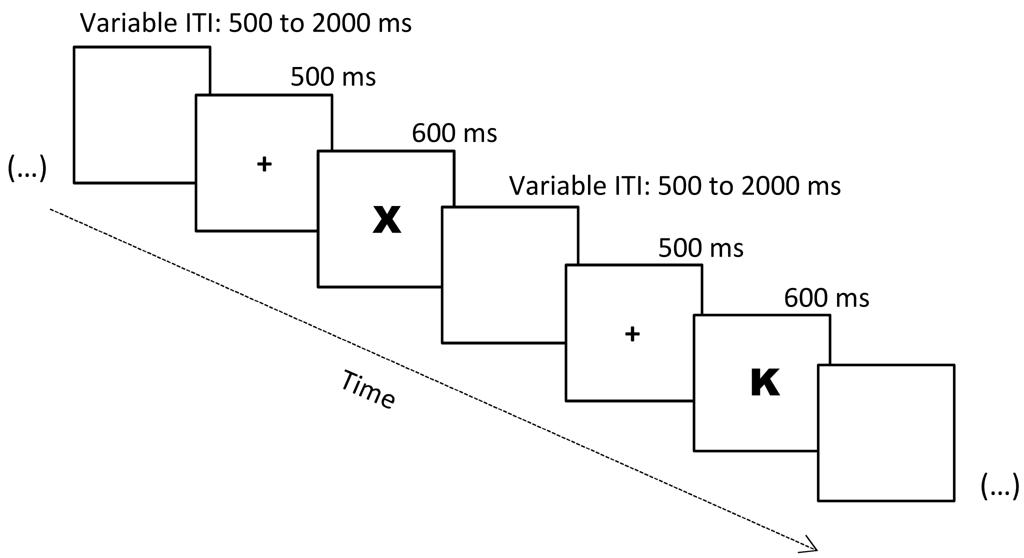


Figure 1. Schematic illustration of the *go/no-go* task.

Choice reaction time task. Following procedures commonly used in several studies (e.g., Kawashima et al., 1996; Liefooghe, 2017; Woods et al., 2015), this task requires a specific motor behavior in response to specific visual stimulus (Mostofsky & Simmonds, 2008). To this end, a green or a red rectangle was randomly presented on the computer screen (on a white background) for a maximum duration of 600 ms, with one of four randomly picked inter-trial intervals (1000, 1500, 2000 or 2500 ms). Each stimulus was preceded by a pre-fixation cross for 500 ms. Half of the rectangles were green, and the remaining were red. Participants were instructed to respond as quickly and accurately as possible to the green rectangle by pressing the “green” keyboard key, and to respond to the red rectangle by pressing the “red” keyboard key. A green sticker was placed on top of the “P” keyboard key and a red sticker was placed on top of the “Q” keyboard key. Participants initially responded to 12 practice trials for familiarization with the task, and then they performed 140 experimental trials. The maximum stimulus presentation (i.e., 600 ms) was the time window for participants to provide their responses. A schematic illustration of this task is presented in Figure 2. We considered the following behavioral measures as dependent variables: correct responses, errors, and reaction times. The correct responses occurred when participants pressed the *green* keyboard key in the presence of the green rectangle, and the *red* keyboard key upon the presentation of the red rectangle. The errors occurred when the participant pressed the colored button that did not correspond to the stimulus color (i.e., the participant pressed the *red* keyboard key in the presence of a green rectangle and vice-versa). Reaction times were measured from the onset of each stimulus until a correct response was produced. The misses are considered when participants did not respond to each stimulus within the time window (600 ms). Considering that the misses are complementary to the correct responses and errors, these will not be reported.

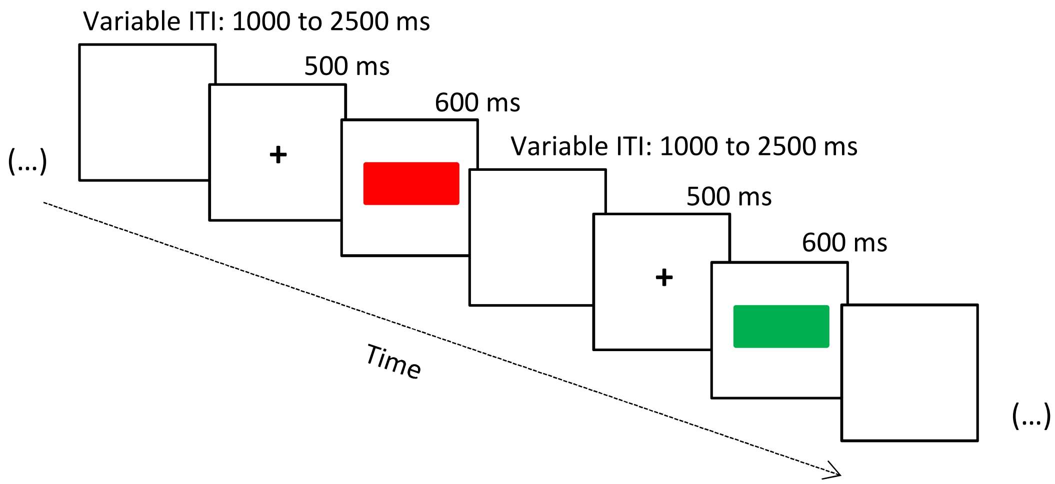


Figure 2. Schematic illustration of the *choice reaction time task*.

Corsi block-tapping (computerized version; Mueller, 2012). This is one of the most used tasks to assess visuo-spatial working memory in different age groups, as well as in healthy and clinical samples (e.g., Brunetti et al., 2014; Pagulayan et al., 2006). The computerized version used in our study was based on its traditional form (Corsi, 1972), and it has been used in several studies (e.g., Mueller & Piper, 2014). In this task, nine blue squares are presented on the white screen of the computer. In each trial, some squares lit up (in yellow), one per second, producing a specific sequence. Two different types of instructions can be given in this task: 1) to repeat the specific sequence by clicking on the squares in the same order they lit up – forward span; or, 2) to repeat the specific sequence clicking on the squares in the backward order they lit up – backward span. In this project, we only applied the forward span procedure. The number of squares included in the sequence increased as the task progressed and two trials were presented for each extension. The first two trials included the lightening of two squares; in the following two trials three squares were lighted, and so on. The task ended automatically when the participant did not reproduce the sequence correctly in the two trials of the same length. The dependent variable was the Corsi span which corresponds to the highest level in which the participant correctly reproduced both sequences plus half point for any other correct sequence that occurs until the participant fails the two trials of a given extension. For example, if the participant responds correctly to the two trials until he/she reaches the sequence of 6, and for this sequence he/she only responds correctly to one of the trials, the (exact) Corsi span would be 5.5.

Rey Complex Figure (RCF) – Figure A (Rey, 1988). This instrument is widely applied to assess several visual cognitive domains, such as visuo-spatial memory in children, adolescents, adults, and older adults (e.g., Caffarra, Vezzadini, Dieci, Zonato, & Venneri, 2002; Senese, De Lucia, & Conson, 2015; Simões et al., 2011). Although there are several administration procedures, the following three tasks are common: copy, immediate recall, and delayed recall. In this project, only the first two administration procedures were used, according to our aims. In the *copy* phase, each participant was instructed to copy the *RCF* in the presence of the figure-stimulus. In the *immediate recall*, three minutes after the conclusion of the copy, each participant was instructed to reproduce the *RCF* without the presence of the figure-stimulus. In Portugal, this test has been applied in different contexts and age groups, and has been subjected to several validation studies (e.g., Bonifácio et al., 2003; Simões et al., 2011). We applied the *copy* phase as a prerequisite to the *immediate recall*, but then we focused mostly on the last procedure which assesses visuo-spatial memory. The *RCF* includes 18 elements that are scored separately. Each element can be scored with 2, 1, 0.5, or 0 points. Two points are given when elements are correctly reproduced; 1 point when the element is distorted, incomplete but properly placed, or complete but placed poorly; 0.5 points are provided when the element is distorted or incomplete and placed poorly; 0 points are given when the element is absent or unrecognizable. According to the original scoring norms that we also followed in our study, the total score ranges from 0 to 36 points in both administrations (copy and immediate recall; Rey, 1988; Rivera et al., 2015).

Visual screening and stimuli recognition. Due to the visuo-spatial nature of the cognitive tasks we administered, an initial visual screening and stimuli recognition was conducted. In this screening, at the beginning of the first session, the researcher presented to each participant several colors and the letters *X* and *K* in paper sheets. Participants were instructed to simply name each stimulus. Participants who did not identify at least one of these stimuli were excluded from the reported data. One older adult did not identify at least one of these stimuli and was, thus, excluded from the reported data.

Sociodemographic questionnaire. This brief questionnaire was created for this project to collect sociodemographic information, such as age, sex, psychological, neurological and learning disorders (e.g., children: Attention Deficit Hyperactivity Disorder; older adults: Alzheimer). In the case of the children, this questionnaire was filled by their legal guardians. In a few cases, the technicians at the daycare institutions helped the older adults to respond to the sociodemographic questionnaire. This instrument allowed us to characterize the sample, as well as to provide information about the inclusion/exclusion criteria described above (e.g., neurological or learning disorders).

Instruments to assess intelligence. The measurement of intelligence is characteristic in cross-sectional studies (e.g., Leiva, Andrés, Servera, Verbruggen, & Parmentier, 2016). Due to time constraints, we opted to assess intelligence using two of the subtests from the *Wechsler Intelligence Scales*. These subtests were applied only to provide information about the eligibility of participants for this research (i.e., exclusion criteria). One of the most used short-forms of these scales is the dyad *vocabulary-blocks design* which has shown good correlation with the total scale and good indexes of validity (e.g., Kaufman & Kaufman, 2001). In the vocabulary subtest, the participant was instructed to orally define words that were presented on a card, one at a time. In the blocks-design subtest, the participant was instructed to reproduce with bicolored cubes figures presented in a notebook, with difficulty level increasing throughout the test. We applied and scored each subtest according to application norms of the Portuguese versions (Wechsler, 2003, 2008). For participants aged 8-16 years, we applied subtests from the *Wechsler Intelligence Scale for Children-III* (WISC-III; Wechsler, 2003); subtests from the *Wechsler Adult Intelligence Scale-III* (WAIS-III; Wechsler, 2008) were administered to participants aged 17 years or more.

Mini-Mental State Examination (MMSE; Portuguese version: Guerreiro et al., 1994). This brief paper-and-pencil instrument is one of the most used tests to screen general cognitive performance. It is composed of 30 questions divided into six cognitive domains: orientation, registration, attention and calculation, recall, language, and constructive capacity. Its application has an approximate duration of 5-10 minutes. In a Portuguese validation study, Guerreiro et al. (1994) obtained values of sensitivity ranging between 63.6% and 77.4%, and of specificity ranging between 90.0% and 96.8% (cited by Freitas et al., 2015). The MMSE is usually administered in different contexts, and has been submitted to several validation studies in Portugal (Freitas et al., 2015; Santana et al., 2016)[6,7]. This instrument was only applied to participants aged 25 years or older, according to existing Portuguese normative data (Freitas et al., 2015). The remaining participants performed a simple attentional task (*d2 attentional test*[8]*;* described briefly in Chapter 1), which took approximately the same amount of time as the time taken to respond to the MMSE.

The cut-off points considered as inclusion/exclusion criterion differed across participants depending on their age and educational level (Freitas et al., 2015). Three older adults were excluded from the data set because they obtained a clinical score in the MMSE.

Instruments to measure anxiety. Given that there is no single Portuguese instrument that allows the assessment of the state-anxiety across all participants, we applied the Portuguese versions of three different instruments that were appropriate to each age group of participants: in children and adolescents aged 8-14 years we administered the *State Anxiety Scale for Children* (Rodrigues, Pandeirada, Bem-Haja, & França, in press); in participants aged 15-29 years we applied the *State-Trait Anxiety Inventory – State Scale* (Silva & Spielberger, 2007); and, the older adults completed the *Geriatric Anxiety Inventory* (Ribeiro, Paúl, Simões, & Firmino, 2011).

The *State Anxiety Scale for Children (SASC)* is one of the independent scales of the State-Trait Anxiety Scale for Children (Spielberger et al., 1973) that measures the level of anxiety individuals are experiencing at the exact moment they are responding to the instrument (state-anxiety). The SASC is composed of 20-items, and the responses are provided by choosing one of the three options (1-3 points) that describe how the participant is feeling at that precise moment. Most studies argue for a two-factor scale,

---

[6] Cut-offs for people aged ≥ 25 years (Freitas et al., 2015).

[7] Cut-offs for people aged ≥ 36 years (Santana et al., 2016).

[8] This task was used solely to equate the duration of the session across age groups. Therefore, performance obtained in this test will not be reported.

which was confirmed in the Portuguese validation study (Rodrigues et al., in press): "anxiety-absent" and "anxiety-present". The total score ranges from 20 (minimal anxiety score) to 60 points (maximal anxiety score). The Portuguese study revealed an instrument with good psychometric properties, such as internal consistency (factor 1_anxiety-absent: α = .863; factor 2_anxiety-present: α = .780) and good test-retest reliability (factor 1_anxiety-absent: ICC = .796; factor 2_anxiety-present: ICC = .720). This scale was translated and validated by our research team since *Mind Garden*[©] (owner of the copyrights of the instrument) informed us about the inexistence of a European Portuguese version of this scale for individuals aged 8-14 years. The validation studies of this instrument (which includes the two independent scales) was a side project conducted during the present project. This work resulted in several presentations and in two publications in peer-reviewed scientific international journals; these are presented in the Appendices 1 and 2 (Rodrigues, Pandeirada, Bem-Haja, & França, 2017; Rodrigues et al., in press).

The *State-Trait Anxiety Inventory (STAI) – State Scale*, similarly to the SASC, consists of 20-items that assess the level of anxiety that participants are facing at the exact moment they are responding to the scale (state-anxiety). The responses are provided by choosing one of the four options (1-4 points). As in the SASC, the Portuguese validation study (age range: 15-69 years old) also proposed a two-factor scale: "state-anxiety absent" and "state-anxiety present". The total score ranges from 20 (minimal anxiety score) to 80 points (maximal anxiety score). The Portuguese validation study revealed a good Cronbach alpha (≥ .87) as well as an acceptable test-retest reliability (r = .59; Silva & Spielberger, 2007).

The *Geriatric Anxiety Inventory* (GAI) is a relatively brief self-report scale composed of 20-items. It assesses the severity of anxiety symptoms in older adults. Each item (e.g., "I often feel tense") requires an answer in a dichotomous response format ("agree" – response scored with 1 point, or "disagree" – response scored with 0 points). The Portuguese adaptation study conducted by Ribeiro et al. (2011) revealed a one-dimensional scale with good psychometric properties, specifically very good internal consistency (α = .964) and test-retest reliability (ICC = .995). Although the GAI does not assess anxiety-state, in its validation study it presented good construct validity,

[©] During the entire process of adaptation and validation of the instrument, and for this project, we complied with all the formal requirements imposed by Mind Garden, Inc, owner of the copyrights of the instrument.

as revealed by correlations with other scales, such as with the *State Scale* of the *STAI* ($r = .631$, $p < .001$).

Instruments to assess depression. Three different instruments were used to assess depression according to the age group of each participant. All instruments have been previously translated and validated to the different Portuguese age groups. Although we used different instruments, they all had a similar conceptual framework and the same aim: to assess depressive symptomatology. The *Children Depression Inventory* (Dias & Gonçalves, 1999) was applied to children and adolescents (8-17 years old). The *Beck Depression Inventory-II* (Martins, 2000) was used in the adults' group (18-29 years old), while the *Geriatric Depression Scale* (Pocinho, Farate, Dias, Lee, & Yesavage, 2009) was administered to the older adults (≥ 65 years old).

The *Children Depression Inventory (CDI)* is one of the most used self-report instruments to assess depressive symptoms in children and adolescents (originally for young-people aged 7-17 years; Kovacs, 1992). Each of the 27-items that compose this instrument consists of three statements. Participants respond by selecting the option that best characterizes their symptoms in the past two weeks (e.g., item 1: a. "I get sad from time to time"; b. "I get sad often"; c. "I'm always sad"). In the Portuguese version used in this study (Dias & Gonçalves, 1999), some items are scored with 0, 1, or 2 points (e.g., item 1, described above) and others in the reverse manner (e.g., item 7: a. "I hate myself"; b. "I do not like myself"; c. "I like myself"). The total score ranges from 0 (absence/minimal depression score) to 54 (maximal depression score) points. The Portuguese version has been validated for young people aged 8-17 years, and revealed good psychometric properties, such as good internal consistency ($\alpha = .80$).

The *Beck Depression Inventory-II* (BDI-II; Martins, 2000) is a self-report inventory composed of 21-items that assess symptoms of depression in adolescents and adults (Oliveira-Brochado, Simões, & Paúl, 2014). For each item, participants choose the option that best describes their state in the last two weeks, including the day they are responding to the questionnaire. Each item is scored from 0 (absence of depressive symptoms) to 3 (severe depressive symptoms) points. The total score ranges from 0 (absence of depression) to 63 (maximal depression score) points. The response options have a *Guttman format*, that is, 4 or 7 response options are provided and the participant chooses only one. The BDI-II has revealed very good psychometric proprieties for the

Portuguese population, specifically internal consistency (α = .91) and test-retest reliability (*r* = .90; Oliveira-Brochado et al., 2014).

The *Geriatric Depression Scale (GDS).* The Portuguese version (Pocinho et al., 2009) of this self-report questionnaire is composed of 27-items with a "yes" or "no" response format (e.g., item 1: "Are you basically satisfied with your life?"). Each response is scored with 0 or 1 point. The total score ranges from 0 (absence/minimal depression score) to 27 (maximal depression score) points. This instrument aims to screen depression in older adults (≥ 65 years old) and revealed very good psychometric proprieties in the Portuguese population, such as internal consistency (α = .906) and temporal stability (*r* = .995).

Chronotype instruments. To assess participants' chronotype (i.e., the circadian preferences), three Portuguese questionnaires were used. For children aged 8-11 years we used the *Children's Chronotype Questionnaire* (Couto et al., 2014). The *Morningness-Eveningness Questionnaire for adolescents* (Rodrigues et al., 2016) was administered to participants aged 12-14 years. For the remaining participants (≥ 15 years old), we applied the adult version of the *Morningness-Eveningness Questionnaire* (Silva et al., 2002). These instruments allowed us to classify each participant as morning-, intermediate-, or evening-type.

Children's Chronotype Questionnaire (Couto, 2011; Couto et al., 2014). This instrument is composed of 27-items that are distributed by three scales: midpoint of sleep, morningness-eveningness scale, and chronotype scale. This questionnaire has been validated for Portuguese children aged 4-11 years, and is responded by the participants' guardians. Although we collected answers to the full questionnaire, we were particularly interested in the morningness-eveningness scale (items 17-26). The total score of the morningness-eveningness scale ranges from 10 (morningness) to 49 (eveningness) points, and showed acceptable psychometric properties for the Portuguese population, such as a Cronbach'α of .71 (Couto, 2011).

Morningness-Eveningness Questionnaire for adolescents (aMEQ). This instrument aims to assess chronotype in Portuguese adolescents and was recently validated by our research group (Rodrigues et al., 2016). The *Morningness-Eveningness Questionnaire,* authored by Horne and Östberg (1976), is considered one of the most applied instruments to assess morningness-eveningness preferences in the world (for a review, see Levandovski, Sasso, & Hidalgo, 2013). It is composed of 19-items: in fourteen questions four response options are presented and participants have to choose the option that best applied to them; the remaining questions require responses using an hourly scale. To our best knowledge, when this project was designed, no validated instruments existed to assess chronotype in adolescents aged 12-14 years. Therefore, we conducted a translation and validation study of the *Morningness-Eveningness Questionnaire* for this age group (aMEQ) which has been published in a peer-review international journal (Rodrigues et al., 2016; this manuscript is presented in Appendix 3). The aMEQ included the 19-items of the original instrument (Horne & Östberg, 1976) and revealed adequate psychometric properties, such as a Cronbach's α of .692 and a Composite Reliability of .702. Scores range from 16 (eveningness) to 86 (morningness) points.

Morningness-Eveningness Questionnaire (MEQ). As mentioned, this is a highly popular instrument to assess circadian preferences. A previous study has validated this instrument for the Portuguese population aged 15 years or higher (Silva et al., 2002). This Portuguese version is composed of 16 original items (the remaining 3 original items were excluded in the validation process). In twelve of the items, participants have to choose the best response option (from a total of four options), and the remaining questions require responses in hourly scales. Its psychometric characterization revealed acceptable internal consistency ($\alpha = .75$). Scores range from 13 (eveningness) to 73 (morningness) points (Silva et al., 2002).

Environmental conditions. Two distinct environmental conditions were created to fulfil our research goals: high- and low-load visual surrounding environments[9]. The first consisted of a white stand that displayed several colored pictures, whereas the low-load visual surrounding environment corresponded to a replica of that same stand but without any pictures (see Figures 3 and 4 for an illustration). In the two environmental conditions, the stand was always placed on the top of the table in which the participant would be performing the tasks. Therefore, while performing the tasks, participants were always facing the platform, similarly to a study conducted by Al-Ayash et al. (2016, p. 200) who studied the effect of different colored walls in learning environments. Additionally, this procedure allowed us to keep constant the visual field across all of the studied age groups, given that the experiment had to be implemented in different

[9] The designations of the two conditions were given only to differentiate the two environments. We did not, objectively, assess their visual load.

settings (schools, daycare centers, and University of Aveiro) that varied in their conditions (e.g., size of the room and color of the space).

A pilot study was conducted to select the pictures that would be presented in the high-load visual environment. The goal of this pilot study was to find sets of pictures that would be of particular interest to each age group, but also to select sets of pictures that would be considered equally interesting by the different age groups. As occurs in real contexts, we are regularly immersed in environments containing a mixture of visual stimuli that are more appealing to some individuals than to others. This study would allow us to mimic such settings in the high-load visual environment.

For this pilot study, a set of 110 pictures freely available on the internet were collected. These included several themes of potential interest to the different age groups. This set of pictures was then presented to independent groups of individuals from each of the four different age groups of interest. Each group was composed of 15 participants: children (7 females) aged 8-12 years (M_{age} = 9.00, *SD* = 1.25); adolescents (7 females) aged 13-17 years (M_{age} = 14.07, *SD* = 1.39); young adults (9 females) aged 18-30 years (M_{age} = 24.07, *SD* = 3.49); and older adults (8 females) aged 65-92 years (M_{age} = 78.87, *SD* = 8.37).

The pilot study was performed in small groups (4-10 participants). The 110 pictures were presented via a PowerPoint presentation using a projector, one at a time, along with an identification number. Participants were initially instructed to rate how appealing each picture was to them using a response scale that varied between “nothing appealing/interesting” (1-point) to “very appealing/interesting” (5-points). Their responses were provided in a paper sheet containing the identification number of each picture and the possible rating values. Participants responded by making a circle or cross on their selected number. Participants were assisted by a researcher in the rating process.

Data were analyzed by age group. For each group, we selected a set of four pictures that would be of high interest to each age group and that, at the same time, had not been considered by another age group as highly interesting. Two other sets of pictures considered to be equally interesting across all age groups were also selected. The Mean values (and *SD*’s) obtained for the set of four pictures rated as more appealing per age group, and for the set of pictures considered to be equally interesting for the four age groups (i.e., the common pictures) are presented in Table 1.

The selected pictures were then displayed in the stand as follows: each of the four rows in the front panel displayed the four pictures of highest interest to each age group, whereas the two sets of common pictures were displayed in the lateral panels. To maximize the potential effect of the environmental manipulation on cognitive performance, the pictures were displayed in specific positions according to the age group of participants as detailed next. The set of pictures considered most appealing to the age group being tested was placed in the most "visible" position, that is in the first row counting from the bottom, the one closer to the laptop screen where most cognitive tasks would be displayed and performed. The order of the remaining sets of pictures corresponded to a decreasing of interest for the different picture sets by each age group.

Table 1

Means (and SD's) obtained for the set of four pictures rated the highest per age group (more appealing pictures) and also for the set of eight pictures rated equally high across age groups.

	Rating group			
Selected pictures per age group	**Children**	**Adolescents**	**Young adults**	**Older adults**
Children	**4.65 (0.17) [1]**	2.90 (0.59) [3]	3.35 (0.71) [3]	2.67 (0.77) [4]
Adolescents	4.26 (0.33) [2]	**3.60 (0.07) [1]**	3.45 (0.60) [2]	2.85 (1.06) [3]
Young adults	3.97 (0.35) [3]	3.30 (0.26) [2]	**4.06 (0.12) [1]**	3.43 (0.52) [2]
Older adults	3.50 (0.30) [4]	2.58 (0.56) [4]	2.68 (0.49) [4]	**4.63 (0.07) [1]**
Common pictures	4.60 (0.06)	3.93 (0.41)	3.89 (0.41)	4.40 (0.23)

Notes: Scores ranged from 1 to 5 points; [#] – correspond to the position in which the set of four pictures was disposed for a given age group. For instance: in the children, the first row (counting from the bottom to the top) included the four pictures considered as most attractive to them [1]; The second, third and fourth rows included those that had been considered most attractive by adolescents [2] (corresponding to the second set of pictures most attractive for children), young adults [3] (the third most appealing set of pictures for children), and older adults [4] (the least attractive pictures for children).

For example, for the children's group, the first row included the four pictures considered as most attractive to them (always counting from the bottom to the top of the stand); the second, third and fourth rows included those that had been considered most attractive by adolescents (corresponding to the second set of pictures most attractive for children), young adults (the third most appealing set of pictures for children), and older adults (the least attractive pictures for children), respectively. In the adolescents, the first row included the four pictures considered more attractive to them, while the second, third and fourth rows included those that had been considered most appealing by young adults, children, and older adults. In the young adults group, the first row displayed the set of four pictures most attractive to them, whereas the second, third and fourth rows displayed the most attractive pictures to adolescents, children, and older adults, respectively. For the older adults group, the first bottom row showed the four most attractive pictures to them, and the second, third and fourth following rows contained the most attractive pictures to young adults, adolescents, and children, respectively. The two lateral panels of the stand contained pictures that were classified as equally appealing by the four age groups. The position of these pictures remained unchanged across all age groups. In the high-load visual environment, participants were exposed to 24 pictures. In Figure 3, we present illustrations of the environmental conditions: The low-load surrounding environment (common condition to all participants) and the high-load environments (specific for each age group). In Appendix 4, we present the pictures used in the high-load visual environment, according to each age group.

2.4. Procedure

This cross-sectional (developmental) study followed a mixed design (cf., Leiva et al., 2016). In all age groups, each participant performed two individual sessions with an interval of 14-23 days (similarly to Rodrigues & Pandeirada, 2015). For the children and adolescents, the sessions occurred in a quiet room at their schools. The older adults performed the two sessions in a quiet room at their daycare centers. The young adults participated in the study in an isolated room at the University of Aveiro. Each participant performed individually each session which was conducted by the researcher, and had an approximate duration of 60 minutes. During each session, participants responded to a set of self-report instruments aiming to collect sociodemographic information and to assess individual variables, and also performed the cognitive tasks. Importantly, only the four cognitive tasks were submitted to the environmental manipulation (Figures 3 and 4).

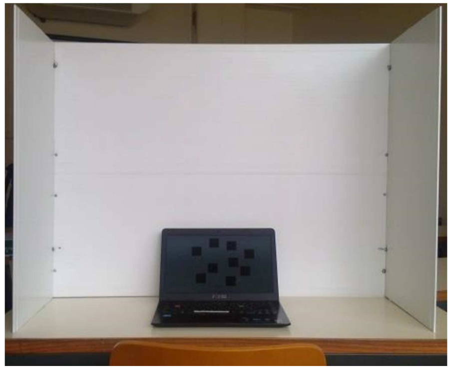
The three computerized tasks (i.e., go/no-go, choice reaction time and Corsi block-tapping) were performed on a 14'' laptop, whereas the Rey Complex Figure was administered in its traditional paper-and-pencil format. As mentioned, in the two environmental conditions, the stand was positioned on the top of the table where the participant would be performing the tasks. Thus, each participant was seated at the desk facing the specific environmental condition, similarly to Al-Ayash et al. (2016) and Rodrigues and Pandeirada (2015). Figure 4 illustrates a simulation of the experimental setting (two environmental conditions) where the four cognitive tasks were performed.

The remaining instruments (e.g., sociodemographic questionnaire, anxiety and depression instruments) were administered outside the stands area (in another table placed in the same room) to prevent an influence of the environmental manipulation in the responses to these instruments. Each participant performed both sessions at about the same time of the day to avoid possible effects of circadian synchrony *vs*. asynchrony (Schmidt et al., 2007). A schematic illustration of the specific procedures adopted in each session is shown in Figure 5.

In the first session, each participant signed an informed consent form. In the children and adolescents' groups, informed written consent was previously obtained from their legal guardians. Then, each participant was submitted to the brief visual screening and stimuli recognition. The MMSE was then applied to the participants aged 25 years or more; the *d2* attentional test, with a response duration similar to that of the MMSE, was applied to the remaining participants in order to maintain the timing of the session events similar across groups. The instrument to assess anxiety was applied immediately before the four cognitive tasks. As mentioned in the materials section, specific anxiety instruments were administered according to the age group of the participant. After responding to these instruments, participants performed the four cognitive tasks in one of the two environmental conditions (low- or high-load visual surrounding environment).

The orders of the environment condition and the cognitive tasks were counterbalanced across participants (see counterbalancing versions in Appendix 5) to avoid learning and order effects. The first session concluded with the application of the chronotype questionnaire.

(a) Low-load surrounding environment



(b) High-load surrounding environments

(b1) **(b2)** **(b3)** **(b4)**

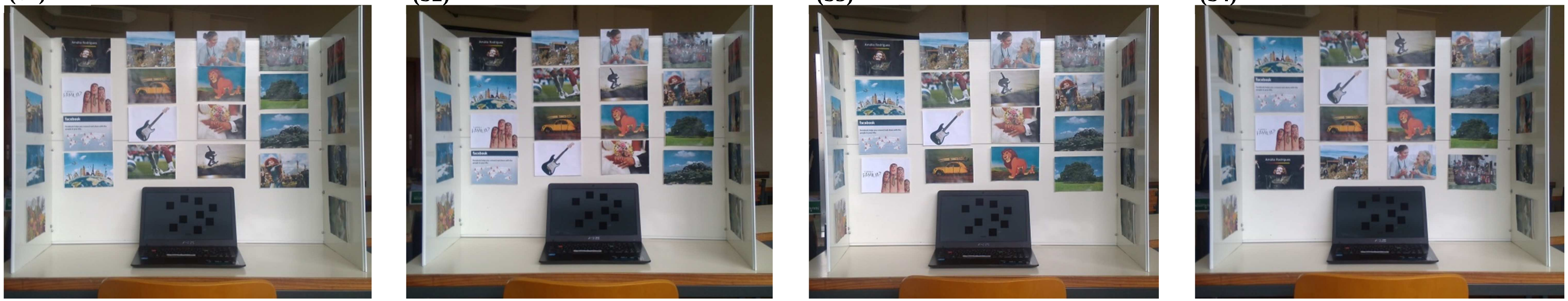


Figure 3. Illustration of the two visual environmental conditions: (a) Low-load visual surrounding environment used with all age groups; (b1) High-load visual surrounding environment applied to children; (b2) High-load visual environment applied to adolescents; (b3) High-load visual surrounding environment applied to young adults; (b4) High-load visual environment applied to older adults.

(a) (b)

Figure 4. Illustration of a young adult's participation (simulations) in (a) the high-load visual surrounding environment and in (b) the low-load visual surrounding environment.

In the second session, we administered the *sociodemographic questionnaire* and the *dyad of the WISC-III* (children and adolescents) or of the *WAIS-III* (young adults and older adults). Then, each participant responded to the *anxiety questionnaire*. Again, while being exposed to the environmental manipulation (in front of the stand), each participant performed the *four cognitive tasks*. For each participant, the order of each task was the same as in her/his first session. The session was concluded with the administration of the *instrument to assess depression* which was specific to each age group, as stated in the materials section.

To exemplify the counterbalancing orders of the environmental conditions and of the cognitive tasks, we describe the specific cases of participants# 1 and #6 according to the counterbalancing versions presented in Appendix 5. Participant# 1 performed the first session in the high-load visual surrounding environment and the second in the low-load visual surrounding environment. In both sessions, he/she performed the cognitive tasks in the following order: 1) Corsi block-tapping; 2) go/no-go; 3) Rey Complex Figure; and, 4) choice reaction time. Participant# 6 completed the first session in the low-load, whereas the second was conducted in the high-load visual environment. In both sessions, the cognitive tasks were performed in the following order: 1) choice reaction time; 2) Corsi block-tapping; 3) go/no-go; and, 4) Rey Complex Figure.

The sessions ended with a debriefing about the purposes of the experiment. The researcher also responded to any questions presented by the participants and thanked their participation offering a small gift.

2.5. Data Analysis

In Chapters 3 and 4, we present the results of the environmental effects (high- *vs.* low-load visual surrounding environment) in children and in adolescents, respectively. Paired *t*-tests were used to compare performance obtained when the tasks where conducted in the low-load *vs.* high-load visual surrounding environment.

Chapter 5 reports the data from the older adults and the young adults' groups. The influence of the surrounding environment (high- *vs.* low-load; within-subject factor) and of age-group (older adults *vs.* young adults; between-subjects factor) on the dependent measures were analyzed using a mixed analysis of variance (ANOVAs). Additional paired *t*-tests were performed within each age group to clarify interactions.

In Chapter 6, we integrated the results from the four age groups: children, adolescents, young adults, and older adults, and conducted mixed ANOVAs including the environmental conditions (high- *vs*. low-load environment) as a within-subject variable, and age group (the four age groups) as a between-subjects variable. To clarify the main effect of age group, multiple comparisons were conducted with Bonferroni adjustments. For each variable, data are also presented graphically by age group and per environmental condition, with polynomial trendlines (order 3).

In Chapter 7, we explored if the environmental effects found in Chapters 3-6 for each age group differed when state-anxiety, depression, and chronotype were considered. The influence of the visual surrounding environment (high- *vs.* low-load environment; within-subjects factor) in each dependent variable from each cognitive task was analyzed while controlling for anxiety and depression (covariates) using analyses of covariance (ANCOVAs). When significant interactions between the environment and the covariate were obtained, follow-up Pearson correlations were conducted between the "effect of the environment" and the covariate involved in the interaction. The influence of the surrounding environment (high- *vs.* low-load environment; within-subjects factor) and chronotype group (synchrony- *vs*. asynchrony-chronotype; between-subjects factor) in each dependent variable from each cognitive measure were analyzed using mixed analyses of variance (ANOVAs).

Detailed information about data analyses are provided in each Chapter. For all of the reported analyses the significance level was $p < .05$.

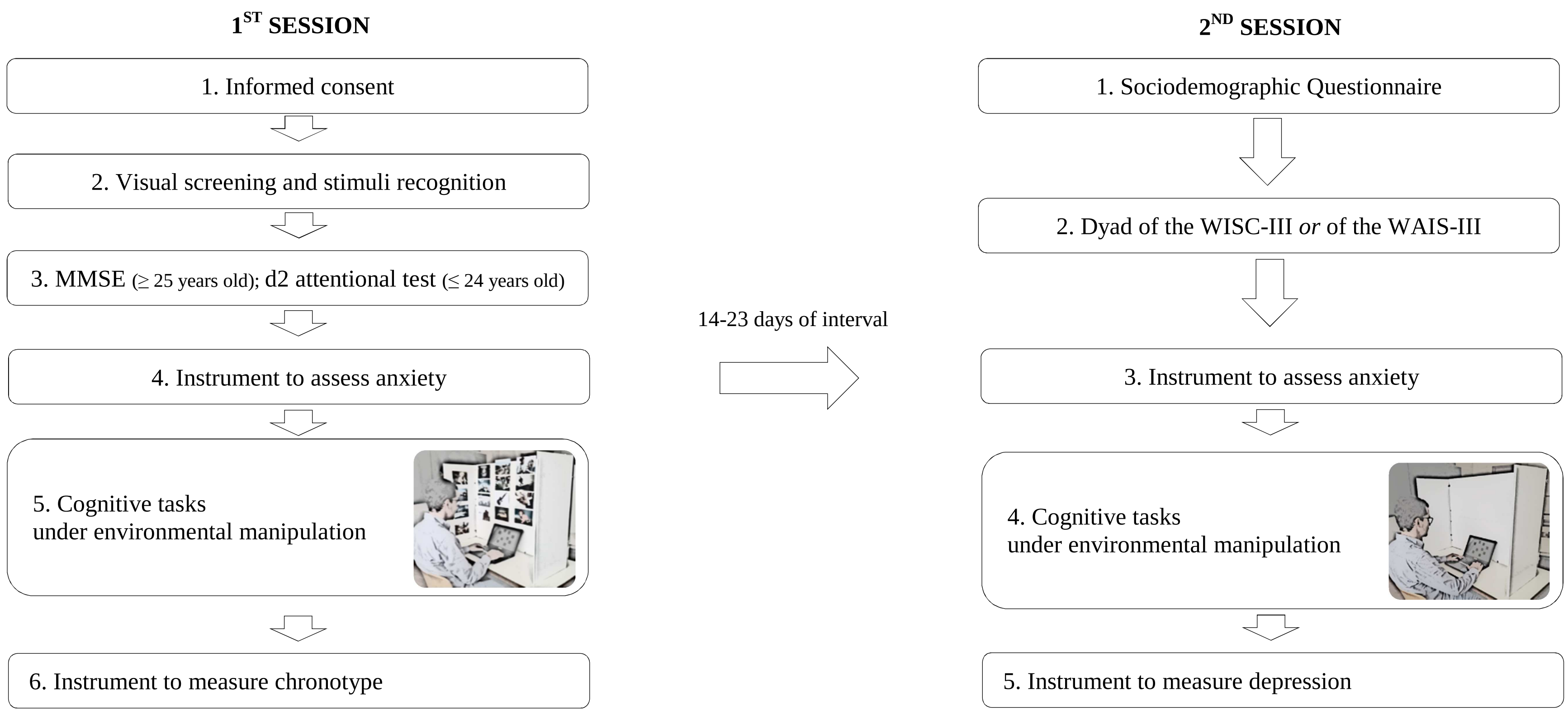


Figure 5. Schematic illustration of the procedures in the 1st and 2nd sessions. Only the administration of the four cognitive tasks was submitted to the environmental manipulation. In the example here provided, in the 1st session, the participant performed the cognitive tasks in the high-load visual environment, while in the 2nd session the cognitive tasks were conducted in the low-load visual environment. However, as we stated, the order of the environmental manipulation was counterbalanced across participants. In both sessions, the instruments applied before the cognitive tasks had a similar duration across all age groups. Each session had an approximate duration of 60 minutes. *[At the end of the 2nd session, an additional self-report instrument was applied to young adults and to the older adults (this took approximately 2 minutes to respond). Given that it is not part of the aims of this thesis, we do not report these data]*.

CHAPTER 3.

When visual stimulation of the surrounding environment impairs cognitive performance: A study with children

The work presented in this chapter is in preparation for submission to an international peer-reviewed journal:

Rodrigues, P. F. S., & Pandeirada, J. N. S. (in preparation for submission). When visual stimulation of the surrounding environment impairs cognitive performance: A study with children.

[Some wording adjustments were made in the formulation here presented as some of the information presented in the Manuscript would be redundant with information provided in previous chapters. For example, the Manuscript in preparation includes several supplemental materials related to the Method which has been described in detail in the General Method chapter (Chapter 2). The Reference list of the Manuscript has been integrated in the final Reference list of this thesis].

Some of the work presented in this chapter has been publicly presented at a scientific meeting:

Rodrigues, P. F. S., & Pandeirada, J. N. S. (2016). *The influence of the visual surrounding environment in cognitive tasks: A study with children*. Poster presented at the International Meeting of the Psychonomic Society, Granada, Spain.

[P. F. S. Rodrigues obtained the *International Graduate Accommodation Award* assigned on a competitive base to graduate students based on their research summaries].

3.1. Abstract

Distraction is widely studied in children, specifically in visuo-spatial cognitive tasks. In these studies, targets and distractors are usually shown in the same display (e.g., on the computer screen). However, children are constantly exposed to a visually-enriched environment and little is known about its influence on children's cognitive performance. Our aim was to investigate whether a high-load *vs*. a low-load visual surrounding environment influences children's cognitive performance as evaluated by simple cognitive tasks. To this end, 64 children (aged 8-12 years) completed two experimental sessions: one in a high-load and the other in a low-load visual environment. In each session, they performed visuo-spatial cognitive tasks: two attentional and two memory tasks. Overall, the results suggested that the high-load visual environment impaired children's cognitive performance as they performed better in the low-load visual environment (e.g., higher percentage of correct responses, higher memory span) as compared with the high-load visual environment.

Given that educational settings (e.g., classrooms) are often enriched with various visual stimuli (e.g., posters, maps, and drawings), we propose an alternative paradigm to study distraction in children that brings together the rigor of experimental psychology and more ecological validity into the exposure to potential distractors. Our results suggest that by influencing basic cognitive processes that support more complex ones, the surrounding environment one typically finds in educational settings (e.g., classrooms enriched with visual stimuli such as posters, paintings, and drawings) can potentially disrupts learning.

Keywords: Children; Visual surrounding environment; High-load visual environment; Low-load visual environment; Visuo-spatial cognitive performance; Distraction.

Highlights:

- We studied the influence of the visual surrounding environment on children's cognitive performance;
- Children performed visuo-spatial attentional and memory tasks while being immersed in a high- and a low-load visual surrounding environment;
- Children's cognitive performance was impaired when tasks were performed in the high-load visual environment;
- We presented an ecological paradigm that more closely mimics the conditions children encounter in their everyday life.

3.2. Introduction

In recent years, an increasing number of studies has been concerned with the influence of the surrounding environment in human health, performance, and behavior (e.g., Steidle & Werth, 2014; Vischer, 2007). Such influence has been addressed in several contexts (e.g., work context: Barry, 2008a; clinical setting: Huisman, Morales, van Hoof, & Kort, 2012), including in learning settings (Fisher et al., 2014; Stern-Ellran et al., 2016). Indeed, environmental characteristics of schools, such as the space design, lightning, color, or sounds, seem to influence academic progress (Barrett et al., 2016). Children learning environments (e.g., an elementary school classroom) are typically colorful and sensory-rich spaces displaying many colorful educational materials. Although these stimulating environments are designed to provide sensory enrichment in early phases of development and to motivate pupils to engage in learning activities (Barrett et al., 2016), little is known about their real effects in learning. Some authors, however, consider that such classroom environments are “excessively stimulating and disrupting” (Stern-Ellran et al., 2016, p. 1), can become a source of distraction (Choi et al., 2014; Fisher et al., 2014; Godwin et al., 2016), and may even have a negative effect in learning (Fisher et al., 2014).

The Environment-Behavior Model proposed by Barrett and Barrett (2010) provides a framework to better understand the environmental factors that could influence children’s performance in classrooms. According to this model, there are three main environmental factors that influence learning gains: naturalness, individualization, and level of stimulation. The first refers to the idea that cognitive performance could be improved when individuals are linked with natural elements, such as plants or pure air. The second denotes that children’s learning is influenced by their own location in the classroom and/or by their connection with the remaining learners. The level of stimulation relates to the color and the complexity of the visual environment of the classroom. Of main interest to the current study is the last element which has also been considered in two previous studies (Fisher et al., 2014; Stern-Ellran et al., 2016).

Fisher et al. (2014) conducted a study to understand the impact of the classroom visual environment in children’s ability to focus their attention during lessons and to learn their contents. Following a within-subjects design, twenty-four children (M_{age} = 5.37 years) participated in several lessons over two weeks. Half of the lessons were performed in a decorated-classroom and the remaining in a sparse-classroom. The decorated-classroom consisted of a laboratory classroom with several visual elements potentially distractors and usually found in elementary schools, such as posters, maps, and drawings. The sparse-classroom was the same space without these stimuli. The order of the environmental manipulation was alternated among lessons. After each lesson, learning gains were assessed via paper-and-pencil tasks. All lessons were videotaped to assess children's behavior, such as their distractibility. The results indicated that the high-decorated environment impaired learning gains. Participants were also more distracted and spent more time off-task in the decorated-classroom than when they were in the sparse-classroom. This work stressed the potential negative effect of the external environment on children's performance. Off-task behaviors or inattention by children have been widely documented in educational settings as one of the factors restraining learning gains (for a review, see Godwin et al., 2016).

Stern-Ellran et al. (2016) aimed to identify the effect of a colorful *vs.* non-colorful surface on children's structured play. To this end, fifteen preschool children (age range: 38-52 months) performed three typical preschool games in a colorful and in a non-colorful surface in two separate sessions. The colorful condition consisted of a surface covered with paper decorated with several images and colors, while the non-colorful condition was a stand covered with a white paper. In each session, participants completed each game individually and without time limit. The order of the conditions was randomized across participants. The two sessions occurred with an interval of 1-2 weeks. Two cameras recorded each session; researchers then coded and analyzed children's behavior. Results indicated that in the colorful surface children had more disruptive behaviors, such as staring away, emitting vocalizations, and missing pieces of the game, than in the non-colorful surface. This study revealed that a high-colorful environment interfered with preschoolers' structured play. The authors speculated about the potential effect of the surrounding environment in attentional, perception and other cognitive processes. However, this study did not include assessment of these specific processes (i.e., cognitive tasks). Given that children are constantly inserted in a specific context that could influence their cognition and behaviors (Barrett et al., 2016; Godwin et al., 2016), studies that look into more basic cognitive processes are warranted.

To our best knowledge, only one study (which was carried out with older adults) investigated the effect of the visual surrounding environment on the performance of basic cognitive processes (Rodrigues & Pandeirada, 2015). In this study, forty Portuguese older adults (M_{age} = 72.98 years) performed two experimental sessions with an interval ranging between 14-21 days: one in a high-load and the other in a low-load environment. In the former, the room where the session occurred contained several visual elements such as posters and photos displayed on the wall in front of the participant. The low-load environment consisted of the same room without these visual elements. In each session, each participant performed two visual attention tasks and the three working memory tasks of the Weschler Adults Intelligence Scale-III (Wechsler, 2008). The orders of the tasks and of the environment were counterbalanced across participants. The results revealed worse performance, predominantly in the attentional tasks (visual tasks), when the tasks were completed in the high-load as compared with the low-load visual surrounding environment. This study showed that the surrounding environment can indeed have damaging effects in simple cognitive tasks. It seems that people in this age range (older adults) have difficulties ignoring distractors that are embedded in their external environment, which may be due to a deterioration of their cognitive functions (Craik & Bialystok, 2006; Sander et al., 2012). Do these results also apply with children, given their immature cognitive system which also makes them susceptible to be affected by potential distractors?

Children have been found to have difficulty not only in ignoring distractors embedded in the environment during learning tasks (Fisher et al., 2014), but also in focusing on target stimuli showed among distractors when these are presented in a given cognitive task (with no consideration of the surrounding environment). In fact, children's distraction in cognitive tasks has been extensively studied with different stimuli and with different age groups (e.g., Gaspelin, Margett-Jordan, & Ruthruff, 2015; Tsubomi & Watanabe, 2017). For instance, in a study by Gaspelin et al. (2015), eighty-four participants (39 children, M_{age} = 4.2 years; 45 adults, M_{age} = 21.5 years) performed a computerized spatial attention task, in which they were instructed to find "spaceships" of a given color while ignoring salient precues which either matched or mismatched the target color. The results revealed that children were slower to find targets and were more susceptible to capture irrelevant information as compared with adults. The authors concluded that "this finding justifies attempts to protect children against distraction (e.g., in educational contexts)" (p. 467). A similar pattern of results was obtained in previous studies in which school-age children were more susceptible to visuo-spatial distraction than adults (Brockmole & Logie, 2013; Hommel, Li, & Li, 2004; Merrill & Conners, 2013; Olesen, Macoveanu, Tegnér, & Klingberg, 2007). Most of the research that has employed cognitive tasks to measure participants' distraction with visuo-spatial elements, typically presents targets and distractors[10] in the same display (e.g., on the computer screen; Gaspelin et al., 2015; Hommel et al., 2004). Distraction is usually measured by the percentage of trials in which the participant focuses his/her attention in the distractor stimuli which results in a lower percentage of correct responses, just to give an example (e.g., Kannass & Colombo, 2007). Although this type of procedure is of theoretical relevance, it might also be interesting to analyze school-age children's distraction when targets displayed on a computer screen (cf. typical cognitive tasks) and distractors embedded in the surrounding environment compete for processing resources. Such a procedure would more closely mimic the conditions children face in their real learning environments (e.g., classrooms). Following the study by Rodrigues and Pandeirada (2015), the present research aimed to investigate the potential effect of a high-load (*vs.* low-load) visual surrounding environment in simple cognitive tasks in a group of school-age children. To this end, sixty-four children (8-12 years old) performed two experimental sessions in which the visual surrounding environment was manipulated. In one of the sessions participants were exposed to a high-load and, in the other, to a low-load visual surrounding environment. In each session, each participant performed two visual attention and two visuo-spatial memory tasks.

We focused on cognitive tasks widely used in the literature that assess visuo-spatial inhibition, response selection, and working memory. These cognitive skills are crucial in children's interaction with their surrounding environment, and therefore important to academic success (Vuontela et al., 2013). We predicted that the high-load visual environment would impair children's cognitive performance (Craik & Bialystok, 2006; Fisher et al., 2014).

3.3. Method

3.3.1. Participants

Our sample consisted of 64 Portuguese children aged 8-12 years (32 girls; M_{age} = 10.16, *SD* = 1.36). They were recruited from two groups of schools from the Aveiro district (Portugal). Informed consent was previously obtained from the children's legal

[10] Distractors refer to stimuli present in a situation/task which are not directly related to the task at hand (non-target information). Distractors usually compete with target information and individuals should ignore them to successfully perform the task of interest (Gilbert & Li, 2013).

guardian. Children also expressed their agreement in participating and were informed that they could withdraw from the experiment at any time if they wanted. None of the children that participated suffered from neurologic, psychologic, or learning disorders, according to the information provided by the children's guardians and teachers.

3.3.2. Materials

Sociodemographic questionnaire. This brief instrument included sociodemographic questions (e.g., age, sex, and health condition), that allowed us to characterize the sample and evaluate possible exclusion motives. This was completed by the guardians.

Cognitive tasks. All participants performed four cognitive tasks: two visuo-spatial attention (*go/no-go* and *choice reaction time*) and two visuo-spatial memory tasks (*Corsi block-tapping* and *Rey Complex Figure*). The attentional tasks were programmed and ran by the software E-Prime 2.0 (Schneider et al., 2002). The *Corsi block-tapping* was applied in a computerized version (PEBL; Mueller, 2012) and the *Rey Complex Figure* (RCF) was administered in its traditional format (paper-and-pencil; Rey, 1988).

In the *go/no-go* task (e.g., Steele et al., 2014), the letter *X* or *K* was randomly and singly presented on the computer screen for a maximum period of 600 ms (time window for participants to provide their responses). A fixation cross preceded each letter for a period of 500 ms. The inter-trial interval was one of the following four: 500, 1000, 1500 or 2000 ms. Each participant was instructed: a) to press on the "white" keyboard key as soon as possible when the letter *X* (*go* stimulus) was presented on the computer screen; and b) do nothing when the letter *K* (*no-go* stimulus) was exhibited. A white sticker was placed on the spacebar keyboard key to facilitate responding. The *go* stimulus was presented in 66% of the total trials whereas the *no-go* stimulus was exhibited in the remaining 34% of the trails. One-hundred and forty experimental trials were presented to each participant, after having completed 12 practice trails.

In the *choice reaction time* task (e.g., Kawashima et al., 1996; Woods et al., 2015), children were instructed to respond as quickly and correctly as possible to the red rectangle by pressing the "red" keyboard key and to the green rectangle by pressing the "green" keyboard key; a red and a green stickers were placed on the keyboard keys "Q" and "P", respectively. Each rectangle was randomly exhibited on the computer screen for a maximum period of 600 ms (time window to provide responses). Half of the rectangles were red and the remaining were green. The inter-trial interval was one of the following four: 1000, 1500, 2000 or 2500 ms. A pre-fixation cross (500 ms) preceded each rectangle. Each participant started the task with 12 training trials and then completed 140 experimental trials[11].

In the *Corsi block-tapping*, nine blue squares appeared in the white screen of the computer. In each trial, some squares lit up (in yellow), one per second creating a specific sequence. Participants were instructed to repeat the same sequence clicking on the squares in the same order they lit up (*forward span*) using the computer mouse. The number of lit squares involved in each sequence increased after two trials of a given extension: The first two trials included the lightening of two squares; the following two trials consisted of the lightening of three squares, and so on. When the participant did not reproduce the sequence accurately on the two trials of the same length, the task finished automatically (Corsi, 1972; Kessels et al., 2008; Pagulayan et al., 2006).

The *Rey Complex Figure – Figure A* (RCF; Rey, 1988) is one of the most popular instruments to assess several cognitive domains, in particular visuo-spatial memory (e.g., in children and adolescents: Simões et al., 2011). Although other administration procedures exist, we applied the copy and the immediate recall tasks[12]. In the first, participants were instructed to copy the *RCF* in a paper sheet with the presence of the figure-stimulus. In the immediate recall, three minutes after the conclusion of the copy, participants were asked to reproduce the *RCF* in another paper sheet but now without the presence of the figure-stimulus.

Environmental conditions. Two environmental conditions were created: the high- and low-load visual surrounding environments. The first consisted of a white stand displaying several visual elements whereas the second consisted of a replica of the stand without any visual elements. The pictures used in the high-load visual environment were subjected to a previous pilot-study (for more details, see General Method in Chapter 2). In the two conditions, the stand was placed on the table were the four

[11] Detailed information of the two attentional tasks was provided in the previous General Method chapter (Chapter 2).

[12] The copy was administered as a requirement to the immediate recall. The later assesses visuo-spatial working memory (among other cognitive abilities).

cognitive tasks were performed (see Figure 6 for an illustration of the two environmental conditions).

(a) (b)

Figure 6. Illustration of the two visual environmental conditions. (a) High-load visual surrounding environment; (b) Low-load visual surrounding environment.

3.3.3. Procedure

Following a within-subjects design, each participant attended to two sessions: one in the high-load and the other in the low-load visual environment with an interval between 14-21 days (similarly to Rodrigues & Pandeirada, 2015). The orders of the environment and of the cognitive tasks were counterbalanced across participants (more information was provided in the General Method presented in Chapter 2). Each participant performed the two sessions at about the same time of the day. All sessions occurred in a quiet room of the school being attended by the participant. Given that the cognitive tasks were of visuo-spatial nature, in the first session we conducted a short visual screening and stimuli recognition task. In this task, several colors and letters were presented and participants were instructed to simply name each stimulus (name of the color and letter identification). No participants were excluded due to failure in this screening. Other self-report measures which did not interfere with the environment manipulation nor with the cognitive tasks were applied before and after performing these cognitive tasks; these are not addressed here as they do not relate to the goal of this paper.

3.3.4. Data Analysis

Given that each participant performed the four cognitive tasks in the high-load and in the low-load environment, we used paired *t*-tests to examine the environmental effect in each behavioral variable. In the go/no-go, the variables of interest were: hits, false alarms, and reaction times for hits. In the choice reaction time, we presented results for the following variables: correct responses, errors, and reaction times for correct responses. Memory span was the behavioral variable in the Corsi block-tapping task, whereas total scores in the copy and in the immediate recall were the two variables in the Rey Complex Figure.

3.4. Results

Go/no-go. In the high-load visual environment participants produced a significantly lower percentage of hits as compared to the low-load visual environment, $t(63) = -4.010$, $p < .001$, $d = .397$. No significant differences were obtained in the percentage of false alarms ($p = .893$) nor in the reaction times ($p = .788$). The descriptive values are presented in Table 2.

Choice reaction time. Overall, participants performed better in the low-load visual environment as compared with the high-load visual environment. This pattern of results was obtained in two of the three variables of this task. Specifically, participants had a higher percentage of correct responses, $t(63) = -2.616$, $p = .011$, $d = .318$, and also faster reaction times for correct responses, $t(63) = 2.366$, $p = .021$, $d = .275$, in the low-load than in the high-load visual environment. No significant differences were obtained for the percentage of errors ($p = .108$). See Table 2 for the descriptive values of each variable.

Corsi block-tapping. Participants had better performance in the low-load compared to the high-load visual environment condition, $t(63) = -2.732$, $p = .008$, $d = .337$ (see Table 2 for the descriptive values).

Rey Complex Figure. In this task, we were mostly interested in the procedure that relied on memory performance, the cognitive process of interest here. In the immediate recall, children performed significantly better in the low-load visual environment than in the high-load visual environment, $t(63) = -3.107$, $p = .003$, $d = .328$. No significant differences between the two environmental conditions were obtained in the copy performance suggesting that the differences obtained in the immediate recall cannot be attributed to a priori differences ($p = .267$) (see Table 2 for all of the descriptive values).

Table 2

Descriptive data for the two attentional and the two memory tasks. Mean values (and SD's) are presented for each variable by environmental condition.

	High-load environment	**Low-load environment**
Go/no-go		
Hits (%)* **	**84.90 (13.93)**	**90.12 (12.32)**
False alarms (%)	29.65 (16.67)	29.95 (17.96)
Reaction times (ms)	378.70 (36.88)	377.55 (46.48)
Choice reaction time		
Correct responses (%)*	**73.10 (17.05)**	**78.27 (15.45)**
Errors (%)	10.94 (5.95)	12.51 (9.12)
Reaction times (ms)*	**378.45 (48.81)**	**363.82 (57.17)**
Corsi block-tapping		
Memory span**	**4.39 (.95)**	**4.70 (.89)**
Rey Complex Figure		
Copy (points)#	31.74 (4.42)	32.13 (4.23)
Immediate recall (points)**	**21.75 (6.13)**	**23.76 (6.14)**

Notes: *$p < .05$; **$p < .01$; ***$p < .001$. Statistically significant effects are noted in bold. #The administration of this task was a requirement to the immediate recall task and is not of particular interest to our goals.

3.5. Discussion

"The ability to *hold* or sustain attention to a task or problem in the midst of competition for attentional focus" (Kannass & Colombo, 2007, pp. 63-64) is widely studied in different age groups and with different stimuli (e.g., Gaspelin et al., 2015). In this study, we experimentally manipulated the surrounding environment (high- *vs.* low-load visual surrounding environment) and investigated the effects of this manipulation on children's cognitive performance, particularly in two visuo-spatial attention and two memory tasks. Even though the study of distraction has a relatively long history, studies have relied mostly on procedures where the main task and the distractor are presented on the same display, usually on a computer screen (e.g., Gaspelin et al., 2015). The procedure adopted in this study introduces a more ecologically-valid procedure by trying to mimic the conditions children have to face in their daily activities (e.g., their classrooms). Although a couple of previous studies have addressed a similar question, they did so looking at more global measures (e.g., learning). The present study looked at basic cognitive processes which underlie many other complex processes adopting procedural details pivotal in experimental methodology that have not always been adopted in these last studies (e.g., counterbalancing of the environmental conditions and of the tasks).

Overall, our results revealed that a high-load visual surrounding environment disrupts children's (8-12 years old) cognitive performance as evaluate by the four cognitive tasks administered. Specifically, the high-load visual environment impaired cognitive performance of the children in five of the eight[13] considered variables. In the high-load visual environment participants provided fewer hits (go/no-go task) and correct responses (choice reaction time task). Additionally, children were slower to provide correct responses when they performed the choice reaction time task in the high-load than in the low-load visual surrounding environment. Regarding the memory tasks, the high-load visual environment was detrimental in the two cases (i.e., Corsi span and immediate recall of the Rey Complex Figure).

Our findings are in line with previous studies with younger children in which a decorated classroom impaired children's learning and structured play (Fisher et al.,

[13] Although we presented data related to copy administration of the Rey Complex Figure, this only constituted a prerequisite to the immediate recall procedure, the variable of interest in this work.

2014; Stern-Ellran et al., 2016). The current study differed from these studies, thought, as we used basic cognitive tasks and a more controlled surrounding setting. Our findings could be justified by developmental aspects: children's cognitive capacities are in development, specifically attentional abilities and the capacity to filter relevant information for a given task are still developing (Hommel et al., 2004; Merrill & Conners, 2013). Similarly to Rodrigues and Pandeirada (2015), we speculate that in the high-load condition children faced competing environmental information (stimuli of the tasks and the visual surrounding elements), and the results suggest they might have difficulties to deal with the interference created by the two sources of stimulation. While in Rodrigues and Pandeirada (2015), older adults were impaired by a high-load visual environment, possibly because their cognitive capacities are in decline, in our study, the impairment of the high-load surrounding environment could be justified by the immaturity of the children' cognitive system (Brockmole & Logie, 2013; Craik & Bialystok, 2006).

Previous studies using the typical procedure to investigate distraction in children, in which targets and distractors were presented on the computer screen, have also revealed a detrimental effect of the presence of distractors (e.g., Merrill & Conners, 2013). Our results are also in agreement with such reports. Importantly, we used a more ecological approach that more closely resembles the conditions in which children have to operate in their daily lives while assessing basic processes that are crucial to learning and that are widely used in several contexts (e.g., Vuontela et al., 2013). We can speculate about the implications of these results to children's lives. Given that classrooms are typically colorful and sensory-rich, it is likely that this type of learning environments could hamper their learning gains. Since in the high-load visual environment children provided fewer hits, fewer correct responses, and longer reaction times (choice reaction time task), as well as a worse memory performance, we can ponder how such difficulties can translate into the real classrooms. In high-decorated classrooms, children would be more likely to spend more time off-task and retain less (visuo-spatial) information, as compared to what would happen if they were in a low-decorated classroom. Even thought we did not objectively test these behavioral components in our study, the results from Fisher et al. (2014), in which children's behavior was videotaped and then analyzed, support this suggestion. A combination of the procedure presented in our study along with behavioral measures (e.g., eye tracking, video record) that could inform about the mechanisms that underlie this detrimental effect of a high-load visual surrounding environment should be implemented in future studies. Given that this was the first work employing this procedure to study environmental distraction in children, more empirical evidence is needed to establish the validity of this paradigm and then its practical implications.

CHAPTER 4.

The damaging influence of a high-load visual surrounding environment in visuo-spatial cognitive performance: A study with adolescents

The work presented in this chapter is in preparation for submission to an international peer-reviewed journal:

Rodrigues, P. F. S., & Pandeirada, J. N. S. (in preparation for submission). The damaging influence of a high-load visual surrounding environment in visuo-spatial cognitive performance: A study with adolescents.

[Some wording adjustments were made in the formulation here presented as some of the information presented in the Manuscript would be redundant with information provided in previous chapters; for example, the Manuscript in preparation includes several supplemental materials related to the Method which has been described in detail in the General Method chapter (Chapter 2). The Reference list of the Manuscript has been integrated in the final Reference list of this thesis].

4.1. Abstract

Adolescence is the developmental period between childhood and adulthood in which cognitive processes are still in maturation. Among several mechanisms, the top-down processing, which is closely related to the ability to inhibit irrelevant information from the focus of attention, is crucial for the interaction of individuals with their surrounding environment. Typically, cognitive processes, in particular those related with visuo-spatial processing, are studied using computerized tasks in which targets and distractors are shown in the same display (e.g., the computer screen). Nevertheless, little is known about the influence of a visually-enriched surrounding environment on cognitive performance, particularly in adolescents; we propose an alternative experimental paradigm that addresses this issue in the study of distraction. The goal of this study was to investigate whether a high-load *vs*. a low-load visual surrounding environment influences adolescents' cognitive performance as measured by simple cognitive tasks. Our sample was composed of sixty-four adolescents (aged 13-17 years) who participated in two experimental sessions (one in a high-load and the other in a low-load visual surrounding environment). In each session, four visuo-spatial cognitive tasks (attention and memory) were administered. Overall, the results revealed that the adolescents' cognitive performance was impaired when they performed the tasks in the high-load environment (e.g., fewer hits, correct responses, and more false alarms and errors). The results of this study which combines the experimental rigor of validated cognitive tasks with greater ecological validity in how the potential for distraction is imposed, suggests that more attention should be devoted to the potential effect of the external environment in adolescent's everyday activities (e.g., in classrooms).

Keywords: Adolescents; Surrounding environment; High-load visual environment; Low-load visual environment; Visuo-spatial cognitive performance; Distraction.

Highlights:

- The influence of two visual surrounding environments on adolescents' cognitive performance was investigated;
- Adolescents performed four visuo-spatial cognitive tasks while being immersed in a high-load and a low-load visual environment;
- Overall, adolescents' cognitive performance was better when the tasks were conducted in the low-load visual surrounding environment;
- This paper proposes an alternative experimental paradigm to study distraction that more closely mimics the conditions adolescents face in their everyday life.

4.2. Introduction

Adolescence is a phase between childhood and adulthood with marked brain development (Rubia, 2013; Vijayakumar, Allen, et al., 2016). Consequently, sensory and motor processes, as well as cognitive functions mature during this developmental period (Burggraaf et al., 2017). The ability to manage the enormous amount of stimuli present in the environment in any given moment, which included the capacity to inhibit irrelevant information from the focus of attention, is among these cognitive functions and is absolutely vital for interacting with the surrounding environment (Galotti, 2013).

In particular, two neurocognitive mechanisms, in maturation during adolescence, are essential to select important stimuli while ignoring irrelevant inputs: bottom-up and top-down. The first allow us to select stimuli according to their salience and novelty, whereas the top-down processing allows us to select stimuli according to our goals and expectations: goal-driven selection (Theeuwes, 2010). The still immature cognitive system of adolescents (Konrad, Firk, & Uhlhaas, 2013) makes them more vulnerable to the influence of the external environment. This work focused on visuo-spatial skills that “have often been tested in children and adults but have been less frequently evaluated during adolescence” (Burggraaf et al., 2017, p 1).

Several studies discuss the influence of numerous environmental aspects in many contexts (e.g., academic setting: Barrett et al., 2015; work context; Barry, 2008a). For example, in scholar contexts, academic progress seems to be influenced by environmental characteristics, such as the space design, its light, color, or sound (e.g., Barrett et al., 2015). To promote the best learning conditions in academic settings is definitely a concern of our society (Kuuskorpi & González, 2011). An important model to consider in this topic is the Environment-Behavior Model of Barrett et al. (2015).

According to the Environment-Behavior Model of Barrett et al. (2015), there are three schools design principles that are crucial to good learning: naturalness, individualization, and level of stimulation. The first proposes that “links to nature” (p. 119) (e.g., natural light, classroom temperatures, and its air quality) improve cognitive function and consequently learning gains. Individualization is related to students-centered strategies, such as their position in the classroom. The level of stimulation proposes that the color (Al-Ayash et al., 2016) and the complexity (Almeda, Scupelli, Baker, Weber, & Fisher, 2014; Godwin et al., 2016) of the surrounding environment have an important role in students’ achievements. However, little is known about the influence of the surrounding environment on cognitive performance, particularly when measured by specific cognitive tasks. Given that adolescents are typically exposed to scholar environments with high visual loads, it seems important to understand if this type of surrounding environments influences their cognitive performance in basic processes which underlie learning activities.

One aspect directly related with cognitive development and commonly assessed in typical visuo-spatial cognitive tasks is distraction (Gaspelin et al., 2015). Distraction refers to the inability or difficulty to maintain attention only to target stimuli attending concomitantly to irrelevant information, that is, distractors (Gilbert & Li, 2013). In most studies, specifically with adolescents, targets and distractors are embedded in the same display, usually the computer screen (e.g., Spronk, Vogel, & Jonkman, 2012). A typical procedure in this type of studies consists in presenting letters or numbers in a low- and high-perceptual load. Participants are instructed to identify the letter or number showed on the computer screen, among irrelevant stimuli (distractors) which also are presented on the computer display. The results suggested that as perceptual load increased, processing of the distractors decreased (e.g., Couperus, 2011). However, we are constantly exposed to physical spaces that include several visual stimuli, most of which are frequently irrelevant to the task at hand. A trio of studies have emphasized the influence of visual distractors in learning gains and in cognitive performance when these elements were present in the surrounding environment rather than on the computer screen (Fisher et al., 2014; Rodrigues & Pandeirada, 2015, 2016). This type of procedure provides more ecological validity to the study of the influence of distractors in performance.

Fisher et al. (2014) aimed to study the influence of the classroom's decoration in children's attention and in their learning gains. To this end, twenty-four young children (M_{age} = 5.37 years) attended several lessons over two weeks. Half of the lessons were taught in a decorated-classroom whereas the other half were taught in a sparse-classroom. The decorated-classroom consisted of a laboratory classroom with a high-load of visual elements typically found in schoolrooms, such as maps, pictures, draws, and so on. The sparse-classroom was the same room but without any of these visual elements. The order of the environmental manipulation was alternated among lessons and among participants. After each lesson, children were submitted to a paper-and-pencil test aimed to assess their learning of the presented material. Each lesson was videotaped to assess children's behavior. The results indicated that in the decorated-classroom, learning gains were lower than in the sparse-classroom condition. Children were also more distracted and spent more time off-task in the decorated- than in the sparse-classroom. Other studies have highlighted the need to study the relation between classroom displays and attentional processes (e.g., Almeda et al., 2014).

Following this more ecological paradigm of Fisher et al. (2014), Rodrigues and Pandeirada (2015) conducted a study to explore the influence of visual environmental distractors in cognitive performance of older adults. The authors also created two environmental conditions: a high-load (distracting) and a low-load visual (non-distracting) surrounding environment. In the first, the wall being faced by participants while they were performing simple cognitive tasks was decorated with several colored posters and photos, whereas in the second the same wall was free from any visual elements. In individual sessions, each participant completed two experimental sessions with an interval of 14-21 days between sessions. One of the sessions occurred in the distracting and the other in the non-distracting environment. In each session, each participant performed two visual attention tasks (simple reaction time and go/no-go tasks) and the three verbal working memory tasks from the Wechsler Adult Intelligence Scale-III (WAIS-III; Wechsler, 2008). The order of the environmental manipulation and of the tasks was counterbalanced across participants. Older adults performed worse when the tasks were completed in the high-load environment as compared to the low-load environment. This pattern was particularly evident in the visual attention tasks. The same authors presented in 2016 a preliminary study with thirty-two children (age range: 8-12 years). Following a similar procedure of their previous study with older adults, their aim was to investigate the influence of a high- *vs.* low-load visual external environment on visuo-spatial cognitive performance, measured by typical cognitive tasks (e.g., visual go/no-go). Overall, children’s performance was impaired when they conducted the cognitive tasks in the high-load environment as compared with the low-load environment. Taking into account these results, would the adolescents’ cognitive performance also be influenced by the external environment?

The current study aimed to explore the influence of the visual characteristics of the visual environment in simple cognitive tasks in adolescents. Considering that adolescence is an age group susceptible to attend to irrelevant information because their cognitive functions are still developing (Luna, 2009), we expected that a high-load visual surrounding environment would impair their cognitive performance in visuo-spatial tasks as compared to a low-load visual environment. To this end, sixty-four adolescents (ages: 13-17 years) completed two sessions: one in a high-load and the other in a low-load visual surrounding environment. In each session, each participant performed four visuo-spatial cognitive tasks.

4.3. Method

4.3.1. Participants

Sixty-four adolescents aged 13-17 years (33 girls; M_{age} = 14.44, *SD* = 1.36) were included in this study. They were recruited from two groups of schools from the Aveiro district (Portugal). None had a history of neurological, psychiatric or learning disorders. This study was authorized by the Portuguese Directorate-General for Education and by the Directors of the participant schools. Informed written consents were obtained from all participants and from their legal guardians prior to participation. Inclusion criteria were: a) to be aged between 13-17 years (an age range commonly defined as adolescence); b) to recognize all visual stimuli used in the cognitive tasks during a visual screening procedure administered in the first session; c) to have no history of neurological, psychological or learning disorders; and, d) to have normal cognitive scores[14] in the abbreviated forms of the Wechsler Intelligence Scale for Children-III (WISC-III; Wechsler, 2003; participants aged 13-16 years) or of the WAIS-III (Wechsler, 2008; participants aged 17 years). No participants were excluded for any of these criteria.

4.3.2. Materials

In the *visual screening* applied at the beginning of the session, the researcher presented to each participant several colors and the letters *X* and *K* and participants were instructed to simply name each stimulus. A brief *sociodemographic questionnaire* was also administered and consisted of a few questions, such as age, sex, and health condition which allowed us to characterize the sample. The experimental part consisted

[14] According to normative data from the Portuguese population, the standardized scores obtained in the WISC-III or WAIS-III were: 13-16 years old (vocabulary: *M* = 12.15; *SD* = 1.94; cubes: *M* = 10.81; *SD* = 1.48); adolescents aged 17 years (vocabulary: *M* = 12.80; *SD* = 2.95; cubes: *M* = 13.00; *SD* = 2.00). More information is provided in Chapter 2.

of four visuo-spatial cognitive tasks: two attentional and two memory tasks described next.

Go/no-go. This is a widely used task to assess inhibition in adolescents. In this task, the letter *X* or *K* appeared randomly and individually on the computer screen for a maximum duration of 600 ms; this also corresponded to the time window for participants to register their responses. Each letter was preceded by a fixation cross for 500 ms and then by one of the following intervals: 500, 1000, 1500 or 2000 ms. A schematic illustration is provided in Figure 7. The following instruction was given for this task: "Press as soon as possible and accurately in the *white* keyboard key when the letter *X* is presented on the computer screen and do not respond when the *K* letter is displayed". The *go* (*X*) stimulus appeared in 66% of the trials and the n*o-go* (*K*) in 34%. A white sticker was placed on the "space" bar keyboard key for easiness of response. The task was composed of 140 experimental trials; a set of 12 practice trails preceded these trials. The behavioral measures in this task were: hits (i.e., the percentage of *go* stimuli to which the participant provided a response), false alarms (i.e., the percentage of *no-go* stimuli to which the participant provided a response), and reaction times for the hits (i.e., the time that elapsed between the stimuli presentation and the occurrence of the response to the *go* stimuli) (e.g., Steele et al., 2013; Vidal et al., 2012).

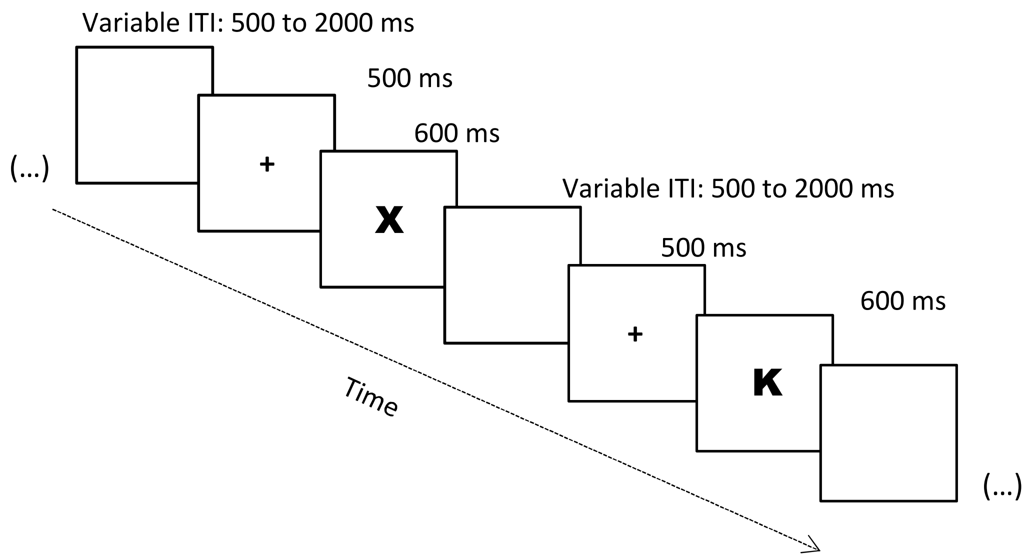


Figure 7. Schematic illustration of the *go/no-go* task. The letter *X* was the target-stimulus and the letter *K* was the non-target stimulus.

Choice reaction time. This task required two specific responses to two distinct stimuli (response selection). Each participant was instructed to press as soon as possible and correctly in the red keyboard key when a red rectangle appeared on the computer screen and to press in the green keyboard key when a green rectangle was presented. Each stimulus was presented singly and randomly in 50% of the trials for a maximum of 600 ms (time window to provide responses). Each rectangle was preceded by a fixation cross of 500 ms and followed by an interval ranging between 1000-2500 ms. After completing 12 practice trails, each participant performed 140 experimental trails. See Figure 8 for a schematic illustration of this task. The behavioral measures in this task were: correct responses (i.e., when participants pressed the green in the presence of the green rectangle, and the red keyboard key in the presence of the red rectangle), errors (when participants pressed the colored button that did not correspond to the stimulus color), and reaction times to correct responses (measured from the onset of each stimulus until a correct response was produced) (e.g., Kawashima et al., 1996; Woods et al., 2015).

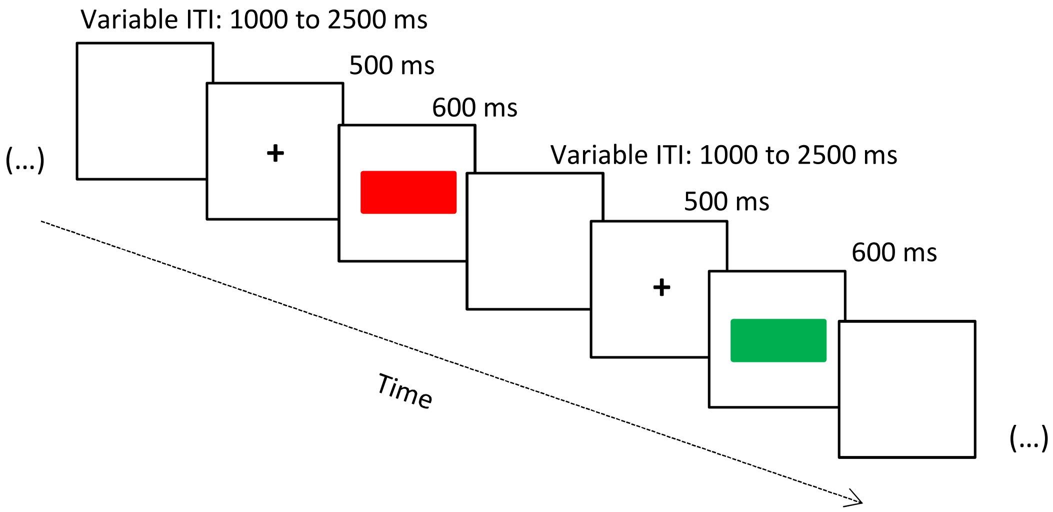


Figure 8. Illustration of the *choice reaction time task* procedure. Each stimulus (red and green rectangles) required a specific response.

Corsi block-tapping. This task is commonly used in different populations to assess visuo-spatial working memory, namely in its computerized forms (e.g., Brunetti et al., 2014). In this study, we used the computerized version of Mueller (2012) in which nine blue squares appeared on the white screen of the computer. In each trial, some squares lit up (in yellow), one per second creating a specific sequence. It was required that participants repeated the same sequence by clicking on the squares in the same order they lighted up (*forward span*). The initial two trials comprised a sequence of two squares; the following two trials consisted of three squares, and so on. After two wrong trials of the same length, the task was ended (e.g., Corsi, 1972; Kessels et al., 2008). The memory span is the dependent variable.

Rey Complex Figure (RCF) – Figure A (Rey, 1988). This instrument is widely-applied instrument to assess several cognitive domains, such as visuo-spatial working memory (Simões et al., 2011). In this study, we were interested in the immediate recall procedure, although the copy procedure was applied as a requirement for the immediate recall. In the copy, each participant was instructed to copy the RCF in the presence of the figure-stimulus. No time limit was imposed for this task. A sheet of paper and a pencil were provided to the participant who was instructed to draw the figure as closely as possible to the original (i.e., with a similar size and all possible details). Three minutes after the conclusion of this task, the participant was asked to replicate the RCF on another sheet of paper, but without the presence of the figure-stimulus; this was the immediate recall procedure. The score of highest interest was the one from the immediate recall task, although we also present the score from the copy administration for control purposes. Scoring was done following the rules of the European Portuguese version of the RCF; higher values correspond to better performance (Rey, 1988).

Visual environmental conditions. Similarly to Rodrigues and Pandeirada (2015, 2016), two distinct environmental conditions were created: the high-load and the low-load visual surrounding environments. The first consisted of a white stand displaying several pictures considered to be attractive to adolescents according to the data obtained in a pilot study (described in the General Method in Chapter 2). The low-load condition was a replica of this white stand but containing no pictures or other visual elements. The stand was placed on top of the desk where participants performed the cognitive tasks. In this created environment, adolescents faced either the high- or the low-load visual environment while they performed the four cognitive tasks (similar procedure with colored walls: Al-Ayash et al., 2016). This procedure of creating the environmental conditions ensured they were kept constant across all participants even when the data were collected in different schools and rooms. An illustration of the two environments is presented in Figure 9.

(a) (b)

Figure 9. Photos of the two environmental conditions (a) High-load visual surrounding environment; (b) Low-load visual surrounding environment. Details about the selection and positioning of the pictures used in the high-load visual environment were explained in the General Method (Chapter 2) of this thesis.

4.3.3. Procedure

Following a within-subjects design, each adolescent performed two individual sessions with an interval of 14-23 days (similarly to Rodrigues & Pandeirada, 2015). Each session was led by the researcher and had an approximate duration of 60 minutes. Each session was conducted in an isolated room of each school: one session occurred in the high-load visual environment and the other in the low-load visual environment. Only the four cognitive tasks were submitted to the environmental manipulation (Figure 9). The three computerized tasks (i.e., go/no-go, choice reaction time and Corsi block-tapping) were performed on a 14’’ laptop, whereas the Rey Complex Figure was administered in its traditional paper-and-pencil format. The remaining instruments were administered in the same room but in an area with no exposure to the stands as we did not intend this manipulation to potentially influence their responses to these instruments. Each adolescent performed the two sessions at about the same period of the day. The orders of the environmental condition and of the cognitive tasks were counterbalanced across participants (see Appendix 5). Other self-report questionnaires were applied but they did not interfere with the environmental manipulation nor with the cognitive tasks; these are not addressed here given that they are not related to the aim of this paper.

4.3.4. Data Analysis

Given that each participant performed the four cognitive tasks in the high-load and in the low-load surrounding environments, we used paired *t*-tests to examine the environmental effect in each behavioral variable identified above in the tasks' description.

4.4. Results

Go/no-go. Adolescents performed better in the low-load than in the high-load visual surrounding environment in two of the three variables of this task. Specifically, participants had a significant higher percentage of hits, $t(63) = 3.279$, $p = .002$, $d = .521$, and lower percentage of false alarms, $t(63) = 4.313$, $p < .001$, $d = .604$, when the task was performed in the low-load as compared with the high-load visual environment. Regarding reaction times, no statistically significant difference was obtained ($p = .331$). The descriptive values for all of these variables are presented in Table 3.

Choice reaction time. The participants provided a significantly higher percentage of correct responses, $t(63) = 3.348$, $p = .001$, $d = .584$, and a significantly lower percentage of errors, $t(63) = 2.740$, $p = .008$, $d = .389$, when the task was performed in the low-load visual surrounding environment than in the high-load visual environment. No significant differences were obtained for the reaction times for correct responses ($p = .742$). See Table 3 for the descriptive values of these variables.

Table 3

Means (and SD's) for the variables obtained in the two attentional tasks by environmental condition.

	High-load environment	**Low-load environment**
Go/no-go		
Hits (%)**	**93.16 (9.07)**	**96.77 (3.72)**
False alarms (%)***	**20.48 (14.65)**	**12.87 (10.15)**
Reaction times (for hits; *ms*)	333.08 (39.49)	337.61 (33.00)
Choice reaction time		
Correct responses (%)**	**83.95 (17.58)**	**91.69 (6.46)**
Errors (%)**	**7.99 (7.48)**	**5.48 (5.29)**
Reaction times (for correct responses; *ms*)	347.01 (34.23)	345.62 (33.84)

Notes: ** $p < .01$; *** $p < .001$. Statistically significant effects are noted in bold.

Corsi block-tapping. The high-load visual surrounding environment impaired adolescents' performance in the Corsi block-tapping task as revealed by a lower memory span obtained in this condition as compared with the low-load environment condition, $t(63) = 3.717$, $p < .001$, $d = .486$. The descriptive values are presented in Table 4.

Rey Complex Figure. The results did not reveal significant differences between the performance obtained in the two environmental conditions in the immediate memory, $t(63) = 1.333$, $p = .187$. In the copy administration (a requirement for the immediate recall), the results also revealed no statistically differences ($p = .248$). In Table 4, we present the descriptive values.

Table 4

Means (and SD's) for the variables obtained in the memory tasks by environmental condition.

	High-load environment	**Low-load environment**
Corsi block-tapping		
Memory span* **	**5.06 (1.12)**	**5.56 (0.93)**
Rey Complex Figure		
Immediate recall	28.58 (3.22)	29.09 (3.45)
(Copy)[#]	32.88 (2.60)	33.07 (2.88)

Notes: ****p* < .001; [#] The administration of this task was a requirement to the immediate recall task and is not of particular interest to our goals. Statistically significant effect is noted in bold.

4.5. Discussion

The present work aimed to study the effect of a high- *vs.* a low-load visual surrounding environment in four visuo-spatial cognitive tasks in a group of adolescents. The tasks administered assessed inhibition, response selection and working memory for visuo-spatial information which are crucial skills in adolescents' everyday activities (e.g., Gabrieli & Norton, 2012; Green, Bunge, Briones Chiongbian, Barrow, & Ferrer, 2017). This age group is positioned between childhood and adulthood and corresponds to a period in which cognitive functions transit from an immature state to an adult-level – peak of cognitive development (Luna, 2009). As we mentioned in the Introduction, understanding how adolescents allocate their attention is decisive to comprehend their cognitive development, and most importantly to adapt their quotidian contexts (e.g., classrooms) in a way that maximizes their performance. Distraction is one of the topics widely studied for these reasons, but the traditional paradigms studying it have placed targets and distractors in the same display, characteristically the computer screen (Couperus, 2011; Spronk et al., 2012). The novelty of this work was to use a procedure that more closely mimics a real setting, similarly to the procedure used by Fisher et al. (in children; 2014) and by Rodrigues and Pandeirada (in older adults: 2015; in children: 2016). To this end, a group of adolescents performed four cognitive tasks that used validated procedures and investigated the effect of the presence of visual surrounding distractors in their performance. This type of procedure more directly addresses principles from the environment-behavior theories which stress the role of the surrounding environment in our behaviors (Barrett et al., 2015; Godwin et al., 2016). However, little is known about the influence of visual surrounding distractors in visuo-spatial cognitive performance measured by specific cognitive tasks (as highlighted by Choi et al., 2014), particularly in adolescents. We used a within-subject design and counterbalanced the orders of the environmental conditions and of the cognitive tasks, which also provides strength to our procedure. We then compared performance (e.g., percentage of correct responses, memory span) obtained when the tasks were conducted in the high-load visual surrounding environment with that obtained when they were carried out in the low-load visual surrounding environment (e.g., Rodrigues & Pandeirada, 2015). Our results suggested that adolescents (13-17 years old) are susceptible to the influence of visual elements when these are displayed in their surrounding environment (our high-load visual surrounding condition). Specifically, the adolescents' performance was impaired in five of the eight[15] considered variables when the tasks were conducted in the high-load compared with the low-load visual surrounding environment. The results were consistent in the two attentional tasks, specifically in hits, correct responses, false alarms, and errors, whereas no effect was found on the reaction times of the two tasks. The environmental effect was also observed in one of the two memory tasks. Overall these results are in line with the preliminary study of Rodrigues and Pandeirada (2016) in which children aged 8-12 years performed worse in the high-load as compared with the low-load visual surrounding environment; interestingly, the adolescents (our study) presented a better performance in the two attentional tasks and in the Corsi block-tapping when these were conducted in the low-load visual environment, as in the study of Rodrigues and Pandeirada (with children; 2016).

Our results can be justified by the fact that adolescents have not yet a full maturation of their cognitive system, in particular of the top-down behavioral control (Luna, 2009). Indeed, we are constantly immersed in a surrounding environment flooded by visual stimuli that tend to capture our attention and guide our behaviors, but

[15] Although we presented data related to copy administration of the Rey Complex Figure, this only constituted a prerequisite to the immediate recall procedure, the variable of interest in this work.

we are unable to process all of these stimuli. Therefore, one needs to select the inputs to which to direct our attention according to the goals at hand while, simultaneously, inhibit the irrelevant information (Gilbert & Li, 2013). The bottom-up and the top-down are two related processes that describe how selection and inhibition of environmental information occurs (Bitan, Cheon, Lu, Burman, & Booth, 2009; Sobel, Gerrie, Poole, & Kane, 2007). The first alerts us to salient stimuli in our environment according to their visual characteristics, whereas the top-down processing modulates external signals (bottom-up) according to our aims and expectations. A coherent visual perceptual experience depends of the bottom-up salience (i.e., stimulus-driven) and top-down modulations (i.e., voluntary attention). In other words, top-down processing underlies our ability to control the focus of attention and to ignore distractors (Gilbert & Li, 2013; Sobel et al., 2007). The top-down modulation of reflexive/impulsive responses is not yet fully efficient in adolescence (Hwang, Velanova, & Luna, 2010) as the capacity to voluntarily suppress irrelevant behaviours matures from childhood until adulthood. Given that these processing continue in development in adolescents (Burggraaf et al., 2017), we can speculate that in this paradigm that closely mimics a naturalistic context, participants faced a response-competition situation (Lavie, 2010) between the visuo-spatial stimuli of the tasks and those of the surrounding environment. Additionally, according to the principle of “biased competition” of Hunt and Einstein (1981), when people face several inputs they should attend to the important ones (in our study, the tasks) while ignoring irrelevant information (in our study, the visual surrounding elements). Given that adolescents still have their cognitive system in maturation, their capacity to ignore distractors can be unripe (Spronk et al., 2012).

It is interesting to note that our results have a similar pattern as those typically found in traditional paradigms where targets and distractors are shown in the same display (e.g., on the computer screen; Spronk et al., 2012). Importantly, our procedure adds more ecological validity providing results that more likely reflect what can occur in real settings. However, more empirical evidence is needed with the procedure, specifically with other age groups, other forms of environmental manipulations, and other tasks.

This study presents an alternative experimental paradigm to study distraction in adolescents. It joins the few studies that have revealed an effect of the surrounding environment in basic (e.g., simple reaction time; Rodrigues & Pandeirada, 2015), as well as in more elaborate processes (learning gains; Fisher et al., 2014). In their daily activities, adolescents face many situations that likely share some of these characteristics, such as their lessons in classrooms containing a high visual load (e.g., posters, maps, and so on). These initial results call our attention to the potential impact that the environmental characteristics can have in some cognitive processes in adolescents. This is an important issue to consider in research contexts (e.g., we should pay attention to the environment in which data collection takes place), but also in applied settings (e.g., in classrooms). Our results suggest that in all cases a visually loaded surrounding environment will impact attentional allocation abilities of adolescents.

CHAPTER 5.

More trouble than good? The influence of the visual surrounding environment in older adults and young adults' cognitive performance

The work presented in this chapter is in preparation for submission to an international peer-reviewed journal as a short report:

Rodrigues, P. F. S., & Pandeirada, J. N. S. (in preparation for submission). More trouble than good? The influence of the visual surrounding environment in older adults and young adults' cognitive performance.

[Some wording adjustments were made in the formulation here presented as some of the information presented in the Manuscript would be redundant with information provided in previous chapters; for example, the submitted paper includes several supplemental materials related to the Method which has been described in detail in the General Method (Chapter 2). The Reference list of the Manuscript has been integrated in the final Reference list of this thesis]**.**

Some of the work presented in this chapter has been publicly presented at scientific meetings:

Rodrigues, P. F. S., & Pandeirada, J. N. S. (2017). *Staying focused! Cognitive performance impaired by the environment in elderly but not in young adults.* Poster presented at the 12th National Meeting of the Portuguese Association of Experimental Psychology, University of Porto, Portugal.

Rodrigues, P. F. S., & Pandeirada, J. N. S. (2016). *O efeito de elementos visuais do ambiente circundante no desempenho cognitivo de idosos e jovens-adultos [The effect of surrounding visual elements in cognitive performance of older adults and young adults]*. Oral communication presented at the Cycle of Conferences Under Investigation: Psychology@UA, University of Aveiro, Portugal.

Rodrigues, P. F. S., & Pandeirada, J. N. S. (2015). *Can the surrounding environment influence cognitive performance? A study with elderly*. Poster presented at the 2nd National Congress of Psychology Conversations & the 1st International Conference of Active Ageing, University of Coimbra, Portugal.

Rodrigues, P. F. S., & Pandeirada, J. N. S. (2015). *When too much leads to less: A richer environment leading to poorer cognitive performance in the elderly.* Poster presented at the Research Day, University of Aveiro, Portugal.

Rodrigues, P. F. S., & Pandeirada, J. N. S. (2015). *Stimulation in elderly is desirable, but not always: The effect of the surrounding environment in cognition.* Poster presented at the 10th National Meeting of the Portuguese Association of Experimental Psychology, Faro, Portugal.

Rodrigues, P. F. S., & Pandeirada, J. N. S. (2015). *The influence of environmental distractors in attentional and memory visuospatial tasks.* Poster presented at the International Convention of Psychological Science, Amsterdam, The Netherlands.

Rodrigues, P. F. S., & Pandeirada, J. N. S. (2014). *O efeito de ambientes distrativos em tarefas atencionais e de memória de trabalho: Um estudo com idosos [The effect of distracting environments in attentional and working memory tasks: A study with older adults]*. Poster presented at the IX Iberoamerican Congress of Psychology and 2nd Congress of the Order of Portuguese Psychologists, Lisboa, Portugal.

5.1. Abstract

Objectives: Research has revealed that cognitive performance of older adults is impaired in tasks where distractors are embedded in the same display as the targets. Using a paradigm that more closely resembles our everyday experiences, we explored if this same effect would occur when distractors are presented in the surrounding environment both in older and in young adults.

Method: 64 older adults and 64 young adults performed four visuo-spatial cognitive tasks (go/no-go, choice reaction time, Corsi block-tapping, and Rey Complex Figure) in two distinct environmental conditions: high- *vs.* low-load visual surrounding environment.

Results: Overall, the older adults performed worse than the young-adults confirming expected age-related differences on cognitive performance. Performance of the older adults, but not of the young adults, was impaired when tasks were completed in the high-load as compared to the low-load visual surrounding environment.

Discussion: Our results suggest that the older adults have difficulties ignoring irrelevant information not only when targets and distractors are in the same display (as revealed by the typical procedure), but also when these are present in the surrounding environment. Potential applications of this more ecological paradigm are presented.

Keywords: Visual surrounding environment; High-load environment; Low-load environment; Visuo-spatial cognitive tasks; Age-related differences.

5.2. Introduction

The study of distraction caused by visual elements that are irrelevant to the task-at-hand is frequent in different age groups (e.g., younger and older adults; Wais & Gazzaley, 2014). In these studies, targets and distractors are usually presented in the same display (e.g., the computer screen; Lavie, 2010; Wais & Gazzaley, 2014). For example, in the studies conducted by Lavie (2005, 2010), a target letter had to be detected among distractor letters while both were presented on a computer screen. Although this type of studies is crucial in cognitive psychology, in our everyday life most distractors exist in our surrounding environment. However, research has not yet systematically explored their potential distraction effect in simple cognitive domains (Choi et al., 2014).

The influence of several environmental aspects (e.g., space color, lightning) has been investigated in behavioral and/or emotional domains (Barrett et al., 2015; Devlin & Andrade, 2017; Gifford, 2007), but little is known about their impact on cognitive processes. Fisher et al. (2014) provided an exception in a study showing that a decorated classroom (containing typical posters and drawings) impaired children's learning as compared with a non-decorated classroom. Rodrigues and Pandeirada (2015) presented an initial study in which older adults performed cognitive tasks (e.g., simple reaction time; digit span) in two different settings: one containing potentially visual distracting elements in wall participants were facing while performing the tasks (e.g., posters and paintings), and another where these were absent. Overall, the older adults performed better in the distractors-absent condition, particularly in the attentional tasks (visual tasks).

The present cross-sectional study aimed to further investigate how the presence of visual elements in the surrounding environment (using a new manipulation procedure) influences performance on a different group of cognitive tasks. Furthermore, this was done with both older adults and young adults. Because the older adults seem to experience difficulties in ignoring visual distractors (Campbell, Grady, Ng, & Hasher, 2012; Craik & Bialystok, 2006), we predicted they would perform worse in the visually-loaded environment. No such effect was expected in the young adults given that their cognitive performance is at peak levels (Craik & Bialystok, 2006). Each person participated in two sessions in which they performed visuo-spatial attention and memory tasks. Importantly, one occurred in a high- and the other in a low-load visual surrounding environment.

5.3. Method

5.3.1. Participants

Our sample included 128 participants: 64 older adults aged 65-94 years (40 female; M_{age} = 79.75, *SD* = 8.06), and 64 young adults aged 18-29 years (49 female; M_{age} = 21.53, *SD* = 3.21). All participants in the final sample were cognitively healthy (see exclusion criterion in the General Method of this thesis). The older adults were recruited from local daycare centers (in these centers, individuals have a relatively independent lifestyle). The young adults were recruited from the academic and local communities. Participants were offered a romance book for their participation. Informed consent was obtained before participation and participants were debriefed at the end.

5.3.2. Materials

Sociodemographic Questionnaire. The former included sociodemographic questions, such as age, sex and health condition.

Cognitive tasks. Participants performed two computerized attentional tasks controlled by E-Prime 2.0 (Schneider et al., 2002).

In the *go/no-go task*, two different letters were randomly presented on the computer screen: *X* or *K* (similarly to Steele et al., 2013; Steele et al., 2014). Participants were instructed to respond as quickly and correctly as possible by selecting the "white" key on the keyboard when the *X* was presented (*go* stimulus; occurred in 66% of the trials), and not to respond when the *K* was presented (*no-go* stimulus; occurred in 34% of the trials). They responded to 140 experimental trials (+ 12 practice trials). Trials began with a fixation cross (500 ms) followed by the letter (maximum period of 600 ms) and one of four variable inter-trial interval (500, 1000, 1500 or 2000 ms). When participants pressed the "white" keyboard key to *go* stimuli, hits were recorded. False alarms occurred when participants pressed this key in response to the presentation of the *no-go* stimuli. Reaction times refer to the time occurring between the *go* stimuli presentation and the participant's response.

In the *choice reaction time task* (e.g., Kawashima et al., 1996; Woods et al., 2015), a green or a red rectangle was randomly presented on the computer screen for a maximum of 600 ms; each stimulus was preceded by a pre-fixation cross (500 ms) and followed by one of four randomly picked inter-trial intervals (1000, 1500, 2000 or 2500 ms). A total of 140 experimental trials was presented (+ 12 practice trials). Participants were instructed to respond as quickly and correctly as possible to each presented color by selecting the key on the keyboard marked with the corresponding color. This task generated correct responses when the corresponding key was selected and errors when the opposite occurred. Response times corresponded to the time occurring between the stimuli presentation and the participant's correct response.

Two memory tasks were also implemented. In the *Corsi block-tapping* (computerized version: Mueller, 2012), nine blue squares were presented on a white screen background. In each trial, a given number of squares lit up, one per second, producing a specific sequence. Participants were instructed to reproduce the sequence by selecting each of the lit up squares according to their presentation order - *forward span*. The extension of the sequence increased as the task progressed. The considered variable was the Corsi span. The *copy* and *immediate recall* administrations of the *Rey Complex Figure* (paper-and-pencil format; Rey, 1988) were also used. In the first, participants were instructed to copy the *Rey Figure* while seeing the figure-stimuli. In the *immediate recall*, 3 minutes after finishing the copy, participants reproduced the *Rey Figure* in the absence of the figure-stimuli. Both administrations were performed without time limit. Performance is scored according to specific rules (Rey, 1988). See General Method of this thesis (Chapter 2) for more details of all tasks.

Environmental conditions. Two environmental conditions created by the authors were used. The high-load visual surrounding condition consisted of a stand containing several visual elements, whereas the low-load visual condition consisted of the same stand without any visual elements (see Figure 10). In both cases, the stand was placed on the table where the participant would be performing the tasks producing a controlled surrounding environment. Materials used in the high-load visual environment were selected from a pilot-study described in detail in the General Method (Chapter 2 of this thesis).

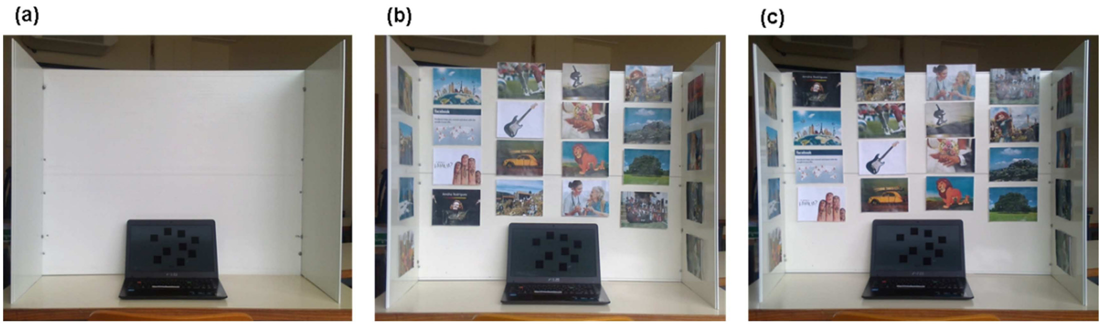


Figure 10. Illustration of the environment conditions. (a) Low-load visual surrounding environment used in both age-groups; (b) High-load visual surrounding environment used with the older adults; (c) High-load visual surrounding environment used with the young adults. Details about the selection and positioning of the images are provided in Chapter 2 of this thesis.

5.3.3. Procedure

Each participant performed two sessions, one in each environmental condition, with an interval of 14-23 days. Sessions always occurred in an isolated room and at about the same time of the day for each participant. The order of the environment and of the cognitive tasks were counterbalanced across participants within each age group (see Appendix 5).

5.3.4. Statistical analyses

The influence of the surrounding environment (high- *vs.* low-load; within-subjects factor) and of age-group (older adults *vs.* young adults; between-subjects factor) on the dependent measures described above were analyzed using mixed analysis of variance (ANOVAs). For the dependent variables described above in each task. Additional paired *t*-tests were performed within each age group to clarify interactions when necessary. Given that the older adults performed worse than young adults in all measures, we refrain to describe this result in every case. For all statistical analyses, an alpha level of .05 was considered.

5.4. Results

The descriptive values of all dependent variables are presented in Tables 5-7 along with the main statistical results; these are detailed next.

5.4.1. Attentional tasks

Go/no-go. For the hits, the main effects of environment and of age group were significant as well as the interaction between them: the older adults had fewer hits when responding in the high-load environment than in the low-load environment. Regarding the false alarms, only the main effect of age group was significant. All effects were also significant for the reaction times to the hits: the older adults were faster to provide their responses when the task was performed in the low-load environment. Further paired *t*-tests revealed that all significant interactions were due to a significant effect of the environment in the older adults but not in the young adults (see Table 5).

Choice reaction time. The repeated measures ANOVA on the percentage of correct responses and errors revealed a significant main effect of age group (young adults obtained more correct responses and fewer errors than older adults), but also significant interactions in the two cases. Follow-up paired *t*-tests revealed a significant effect of the environment for the last variables (correct responses and errors) in the older adults. The older adults performed worse in the high-load environment (with fewer correct responses and more errors). A marginal effect of the environment in response times reflects the tendency for longer response times in the high-load as compared to the low-load environment. The interaction in this variable was non-significant (see Table 6).

5.4.2. Memory tasks

Corsi block-tapping. Significant main effects of the environment, age group and interaction were found on the Corsi span, with the older adults performing worse than the young adults, and a damaging significant effect of the high-load visual environment obtained only for the older adults (see Table 7).

Rey Complex Figure. Young adults' copy[16] and immediate memory were significantly better than that of the older adults, but the main effect of the environment and the interaction were not significant (see Table 7).

[16] The copy procedure was applied as a requirement to the immediate recall (our central variable which is related to visuo-spatial working memory). We present data to the copy procedure, but this is a secondary variable.

Table 5

Means (and SD's) obtained for the hits, false alarms, and reaction times for the hits in young and older adults, and in each environmental condition, for the go/no-go task. The statistical results of the mixed ANOVA (main effect of environment, of age group and interaction between them) are also presented in the Table.

	High-load environment		**Low-load environment**		
	Older adults	Young adults	Older adults	Young adults	
Hits (%)	**61.16**** **(25.70)**	98.14 (5.41)	**70.67**** **(24.81)**	98.61 (3.65)	***Environment:*** $F(1,126) = 9.61$, $p = .002$, $\eta_p^2 = .071$ ***Age group:*** $F(1,126) = 136.62$, $p < .001$, $\eta_p^2 = .520$ ***Interaction:*** $F(1,126) = 7.89$, $p = .006$, $\eta_p^2 = .059$
False alarms (%)	10.47 (9.14)	7.05 (5.06)	9.47 (9.66)	6.38 (5.47)	*Environment:* $F(1,126) = 1.89$, $p = .172$, $\eta_p^2 = .015$ ***Age group:*** $F(1,126) = 7.33$, $p = .008$, $\eta_p^2 = .055$ *Interaction:* $F(1,126) = .076$, $p = .784$, $\eta_p^2 = .001$
Reaction times (ms)	**447.05**** **(63.43)**	346.03 (28.24)	**417.97**** **(74.32)**	346.33 (29.47)	***Environment:*** $F(1,126) = 9.56$, $p = .002$, $\eta_p^2 = .071$ ***Age group:*** $F(1,126) = 113.02$, $p < .001$, $\eta_p^2 = .473$ ***Interaction:*** $F(1,126) = 9.96$, $p = .002$, $\eta_p^2 = .073$

Notes: ** paired *t*-test with $p < .01$; statistically significant effects are noted in bold.

Table 6

Means (and SD's) obtained for the correct responses, errors, and reaction times for the correct responses in young and older adults, and in each environmental condition, for the choice reaction time task. The statistical results of the mixed ANOVA (main effect of environment, of age group and interaction between them) are also presented in the Table.

	High-load environment		**Low-load environment**		
	Older adults	Young adults	Older adults	Young adults	
Correct responses (%)	**47.34*** (23.49)**	94.05 (6.94)	**60.06*** (25.61)**	94.15 (8.64)	***Environment***: $F(1,126) = 12.81$, $p < .001$, $\eta_p^2 = .092$ ***Age group:*** $F(1,126) = 226.99$, $p < .001$, $\eta_p^2 = .643$ ***Interaction:*** $F(1,126) = 12.42$, $p = .001$, $\eta_p^2 = .090$
Errors (%)	**6.93* (6.15)**	2.73 (2.19)	**5.70* (5.29)**	2.97 (2.52)	*Environment:* $F(1,126) = 2.37$, $p = .126$, $\eta_p^2 = .018$ ***Age group:*** $F(1,126) = 24.15$, $p < .001$, $\eta_p^2 = .161$ ***Interaction:*** $F(1,126) = 5.13$, $p = .025$, $\eta_p^2 = .039$
Reaction times to correct responses (ms)	439.16 (65.77)	359.79 (30.07)	429.02 (48.39)	354.45 (32.02)	*Environment:* $F(1,126) = 3.33$, $p = .070$, $\eta_p^2 = .026$ ***Age group:*** $F(1,126) = 120.43$, $p < .001$, $\eta_p^2 = .489$ *Interaction:* $F(1,126) = .320$, $p = .572$, $\eta_p^2 = .003$

Notes: * paired *t*-test with $p < .05$; *** paired *t*-test with $p < .001$; statistically significant effects are noted in bold.

Table 7

Means (and SD's) obtained for the memory tasks (Corsi block-tapping and Rey Complex Figure) in young and older adults, and in each environmental condition. The statistical results of the mixed ANOVA (main effect of environment, of age group, and interaction between them) are also presented in the Table.

	High-load environment		**Low-load environment**			
	Older adults	Young adults	Older adults	Young adults		
Corsi block-tapping **Memory span**	**3.86*** (.90)**	5.58 (.86)	**4.56*** (.73)**	5.56 (.89)	***Environment:***	$F(1,126) = 20.29$, $p < .001$, $\eta_p^2 = .139$
					Age group:	$F(1,126) = 110.40$, $p < .001$, $\eta_p^2 = .467$
					Interaction:	$F(1,126) = 22.20$, $p < .001$, $\eta_p^2 = .150$
Rey Complex Figure Copy	26.30 (5.56)	34.43 (1.84)	26.66 (5.19)	34.66 (1.16)	*Environment:*	$F(1,126) = 2.79$, $p = .097$, $\eta_p^2 = .022$
					Age group:	$F(1,126) = 142.09$, $p < .001$, $\eta_p^2 = .530$
					Interaction:	$F(1,126) = .143$, $p = .705$, $\eta_p^2 = .001$
Immediate recall	18.35 (5.80)	29.30 (5.25)	19.06 (5.61)	29.02 (5.80)	*Environment:*	$F(1,126) = .27$, $p = .606$, $\eta_p^2 = .002$
					Age group:	$F(1,126) = 134.24$, $p < .001$, $\eta_p^2 = .516$
					Interaction:	$F(1,126) = 1.42$, $p = .235$, $\eta_p^2 = .011$

Notes: *** paired t-test with $p < .001$; statistically significant effects are noted in bold.

5.5. Discussion

Our work explored if the presence of visual elements in the external environment would affect cognitive performance in older and young adults. Although visual distraction has been widely studied in different age groups using a variety of tasks (e.g., Lavie, 2010; Wais & Gazzaley, 2014), little is known about what happens when these distractors occur in the surrounding environment. Using a procedure that more closely mimics the conditions faced in our everyday lives, when tasks were performed in the high-load visual surrounding environment, the older adults performed worse in both attention tasks and in one of the memory tasks. Specifically, a significant effect of the environment was obtained for the older adults in four of the six considered variables of the attention tasks, and in one of the two memory tasks. In the remaining variables across tasks, a trend for worse performance in the high-load environment was also found in this age group. The results regarding the attentional performance are consistent with those reported by Rodrigues and Pandeirada (2015) with older adults and with the notion that this age group has difficulty ignoring irrelevant information (Campbell et al., 2012). No effect of the environment was obtained in the Rey Complex Figure which could be related to the form of responding to this task. Being a paper-and-pencil task, attention is directed to a visual field that is less exposed to our distracting panel which is displayed in front of the participant. Thus, it is possible that participants were more capable of maintaining their focus on the task and be less influenced by the surrounding environment. In agreement with the notion that young adults' cognitive abilities are at their best (Craik & Bialystok, 2006), including the capacity to unattend to distractors, their performance was not influenced by our manipulation of the environment.

Besides investigating the effect of the environment on cognitive performance, our study confirmed developmental differences between the two age groups: the older adults performed worse than the young adults in all tasks (e.g., Craik & Bialystok, 2006; Sander et al., 2012).

Our results suggest that dealing with a visually rich external environment can be particularly challenging for older adults even when performing very simple tasks that require their attention and memory. This study joins the few studies that have shown that the surrounding environment affects basic (e.g., simple reaction time in older adults: Rodrigues & Pandeirada, 2015), as well as more elaborate processes (learning gains in children: Fisher et al., 2014). Everyday, older adults face many situations that likely share some of these characteristics such as driving in a road surrounded by advertising posters or having to remember the sequence with which they need to take their medication. Understanding how the external environment affects the bricks that together build more complex processes is essential to help more vulnerable populations thrive in their daily lives.

CHAPTER 6.

Integration of the data from all four age groups

6.1. Brief Introduction

The main goals of this chapter were twofold. The first was to explore if the predicted cognitive performance across age groups denoted in the introductory chapter of this thesis – the inverted U-shaped curve – was replicated in our samples and in the specific tasks we used. The second goal was to present a developmental analysis of the influence of the environmental manipulation (high-load visual surrounding environment *vs.* low-load visual surrounding environment) in attentional and memory tasks used in this project by comparing such influence across age groups. Given that the different age groups have typically different capacities to ignore irrelevant information as described in the introductory chapter, we expected that the environmental manipulation would affect the performance of the four groups in a different manner (Craik & Bialystok, 2006; Hommel et al., 2004; Lavie, 2005; McAvinue et al., 2012; Peverill, McLaughlin, Finn, & Sheridan, 2016). Specifically, we anticipated that children and older adults would be the two groups most affected by the high-load visual environment followed by adolescents. We also anticipated that the young adults, a group in the peak of their cognitive capacities and with a good ability to ignore irrelevant information, would be the group least affected by the environmental manipulation (Craik & Bialystok, 2006).

To fulfill our goals, we integrated the results from the four age groups: children, adolescents, young adults, and older adults, and conducted mixed ANOVAs in which the environmental condition was entered as a within-subject variable, whereas the age group constituted a between-subjects variable. The Bonferroni adjustment for multiple comparisons was used. The results are presented for each task considering the dependent variables described in the previous chapters. For each variable, these data are also presented graphically by age group and per environmental condition. The corresponding descriptive values are also summarized in Appendix 6 for easiness for comparison, and presented in more detail in Chapters 3-5 in which we provided specific analysis for each age group.

6.2. Attentional tasks

6.2.1. Go/no-go

Percentage of hits. A mixed ANOVA revealed significant main effects of the environment, $F(1, 252) = 26.68$, $p < .001$, $\eta_p^2 = .10$, and of age group, $F(3, 252) = 81.43$, $p < .001$, $\eta_p^2 = .492$, as well as a significant Environment x Age-group interaction, $F(3, 252) = 4.27$, $p = .006$, $\eta_p^2 = .048$ (see Figure 11 for a graphical illustration). To clarify the main effect of age group, multiple comparisons were conducted. These revealed that the percentage of hits differed significantly among all age groups (highest $p = .007$, for the comparison between children and adolescents), with the exception of the difference between the adolescents and the young adults ($p = .826$). The results reflect the following pattern: the young adults obtained the best performance, followed by the adolescents and then by children. Performance by the older adults was significantly lower than all other age groups. Underlying the significant interaction is a significant effect of the environment in all age groups with the exception of the young adults (see Chapters 3-5 for the specific age group analysis).

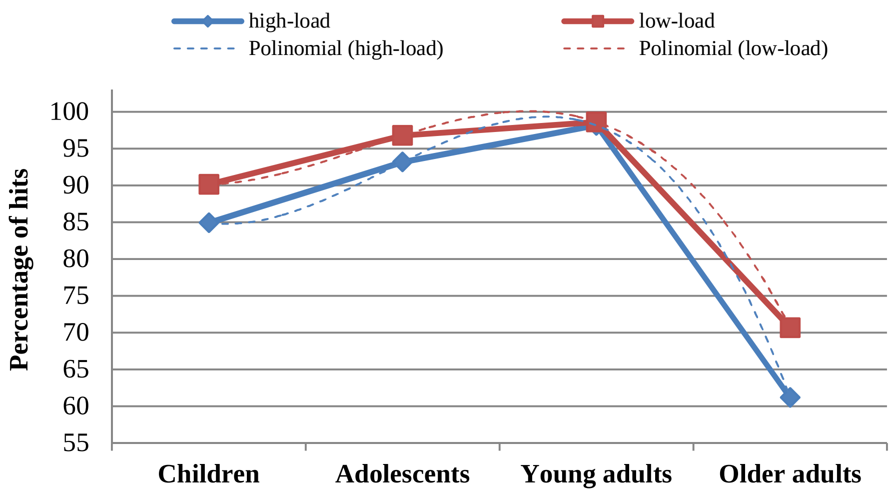


Figure 11. Percentage of hits in the go/no-go task by age group and by environmental condition. The dashed lines correspond to polynomial trendlines (order 3) for each condition and age group.

False alarms. Regarding the false alarms, a similar pattern of results was obtained by the mixed ANOVA: significant main effects of the environment, $F(1, 252) = 8.50$, $p = .004$, $\eta_p^2 = .033$, and of age group, $F(3, 252) = 63.17$, $p < .001$, $\eta_p^2 = .429$, along with a significant interaction between them, $F(3, 252) = 5.53$, $p = .001$, $\eta_p^2 = .062$. The multiple comparisons revealed significant differences of the false alarms among all age groups (highest $p = .002$, for the comparison between adolescents and older adults); an exception was the lack of a significant difference between the young adults and the older adults ($p = .446$). These results indicate that the children's group provided the highest percentage of false alarms, followed by the adolescents, and then by older adults and young adults; these last two groups obtained the lowest percentage of false alarms, with a non-significant difference between them. Underlying the significant Environment x Age-group interaction is the strong significant effect of the environment in the adolescents, and the absence of such effect on the remaining age groups. See Figure 12 for a presentation of the data from all age groups.

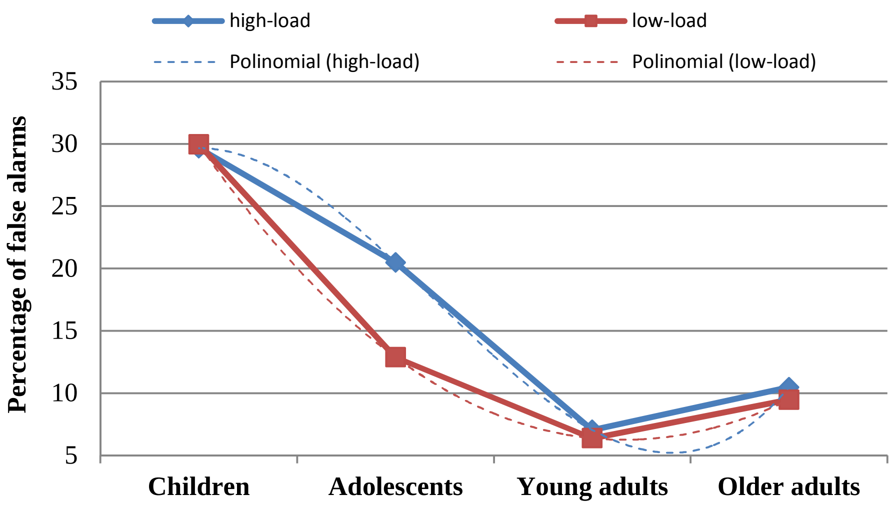


Figure 12. Percentage of false alarms in the go/no-go task by age group and by environmental condition. The dashed lines correspond to polynomial trendlines (order 3) for each condition and age group.

Reaction times. Significant main effects of the environment, $F(1, 252) = 5.11$, $p = .025$, $\eta_p^2 = .020$, and of age group, $F(3, 252) = 72.96$, $p < .001$, $\eta_p^2 = .465$, were also obtained for the reaction times for hits of the go/no-go task. The interaction between the two was also significant, $F(3, 252) = 7.46$, $p < .001$, $\eta_p^2 = .082$. The multiple comparisons among all age groups showed significant differences in almost all cases (*ps* $< .001$), with the exception of the difference between the young adults and adolescents which was not significant ($p = .809$). The older adults were the slowest to provide their hits, followed by children. The young adults and the adolescents were the fastest to respond correctly in this task (with the shortest reaction times), with non-significant differences between them. Underlying the significant interaction is a significant effect of the environment in the reaction times of the older adults. In the remaining groups, non-significant effects of the environment were found (see Chapters 3-5 for specific analysis). See Figure 13 for a graphical representation of the reaction times by age group and by environment.

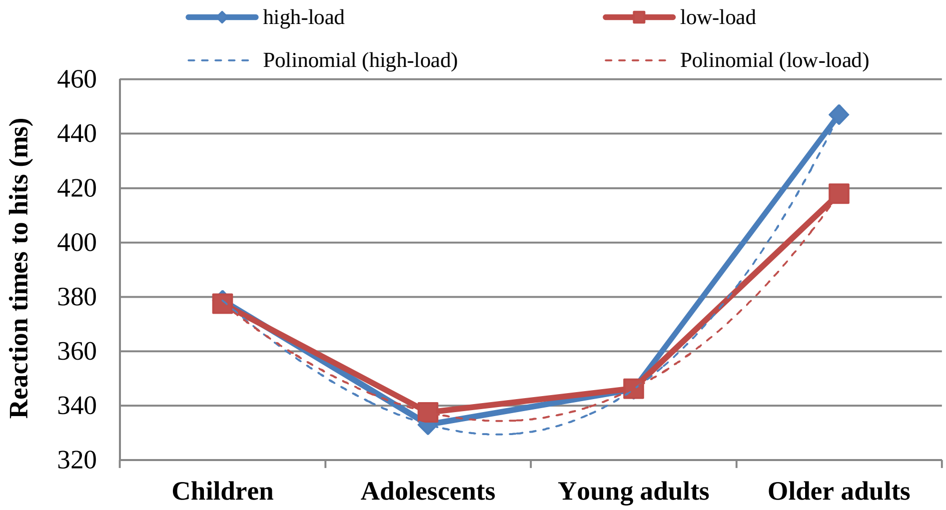


Figure 13. Reaction times (ms) for hits in the go/no-go task by age group and by environmental condition. The dashed lines correspond to polynomial trendlines (order 3) for each condition and age group.

Summary of the go/no-go results. We found the expected inverted U-shaped curve in the percentage of hits, i.e., the older adults and the children obtained the worst performance, whereas the adolescents and the young adults obtained the best achievement. Additionally, the high-load environment had a detrimental effect on hits in all age groups, with the exception of the young adults. This was an expected result because the last group is in the peak of their cognitive capacities with a good ability to filter the irrelevant information (i.e., the visual elements presented in the surrounding environment).

The adolescents and the young adults were the fastest participants to respond correctly to the *go* stimuli. On the other hand, the adolescents produced more false alarms than the young adults and even the older adults. Of note is also the fact that the adolescents were the only age group where we obtained a significant effect of the environment on the false alarms. The older adults obtained a low percentage of hits and a low percentage of false alarms (although young adults had descriptively fewer false alarms). Given that these corresponded to active responses, we can speculate if any motor difficulties that are typical in older adults could have impaired their performance in this task (for a review see: Krampe, 2002; Seidler et al., 2010). Nevertheless, an effect of the environment was obtained for the reaction times only in this group.

6.2.2. Choice reaction time

Percentage of correct responses. The mixed ANOVA revealed significant main effects of the environment, $F(1, 252) = 29.99$, $p < .001$, $\eta_p^2 = .106$, and of age group, $F(3, 252) = 107.90$, $p < .001$, $\eta_p^2 = .562$, as well as a significant Environment x Age-group interaction, $F(3, 252) = 5.01$, $p = .002$, $\eta_p^2 = .056$. The multiple comparisons revealed that the difference between the adolescents and young adults was not significant ($p = .061$), even though it was in the predicted direction (the young adults obtained a higher percentage of correct responses). All other differences among age groups were statistically significant (*ps* < .001), reflecting a lower performance by the older adults, followed by that of the children and then by the adolescents and young adults. This pattern is illustrated in Figure 14. Underlying the significant interaction are significant effects of the environmental condition in all age groups, with the exception of the young adults, as detailed in Chapters 3-5.

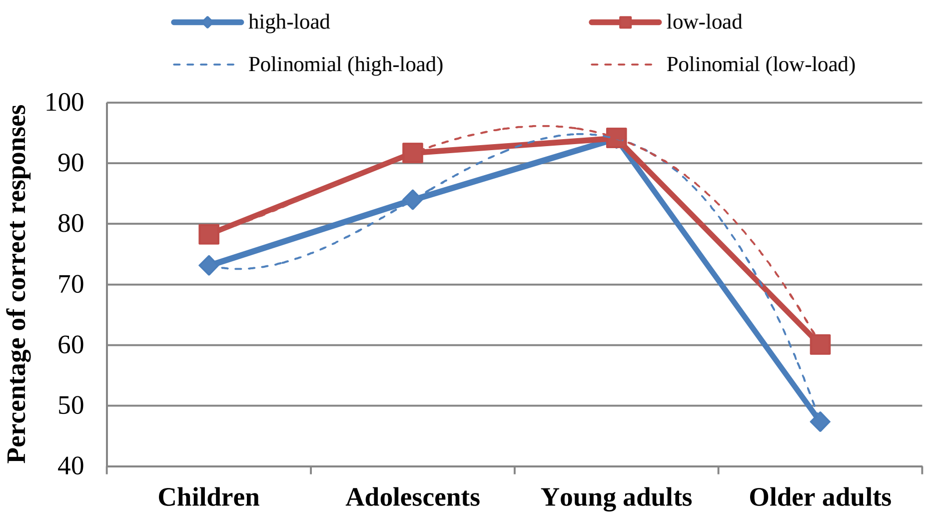


Figure 14. Percentage of correct responses in the choice reaction time task by age group and by environmental condition. The dashed lines correspond to polynomial trendlines (order 3) for each condition and age group.

Errors. Regarding the percentage of incorrect responses, the mixed ANOVA revealed a significant main effect of age group, $F(3, 252) = 32.62$, $p < .001$, $\eta_p^2 = .280$, and a significant Environment x Age-group interaction, $F(3, 252) = 5.73$, $p = .001$, $\eta_p^2 = .064$. The main effect of the environment was not significant, $F(1,252) = 1.70$, $p = .193$, $\eta_p^2 = .007$. The multiple comparisons among age groups resulted in significant differences among all age groups (highest $p = .001$, for the comparison between young adults and older adults), but the difference between the adolescents and older adults ($p > .99$) was not reliable. These results also describe the expected U-shape curve: the highest point was obtained in the children's group, followed by the older adults and the adolescents (which did not differ significantly between them), and finally by the young adults (see Figure 15). Underlying the interaction are significant effects of the environment only in the adolescents and older adults groups (see Chapters 4 and 5, respectively).

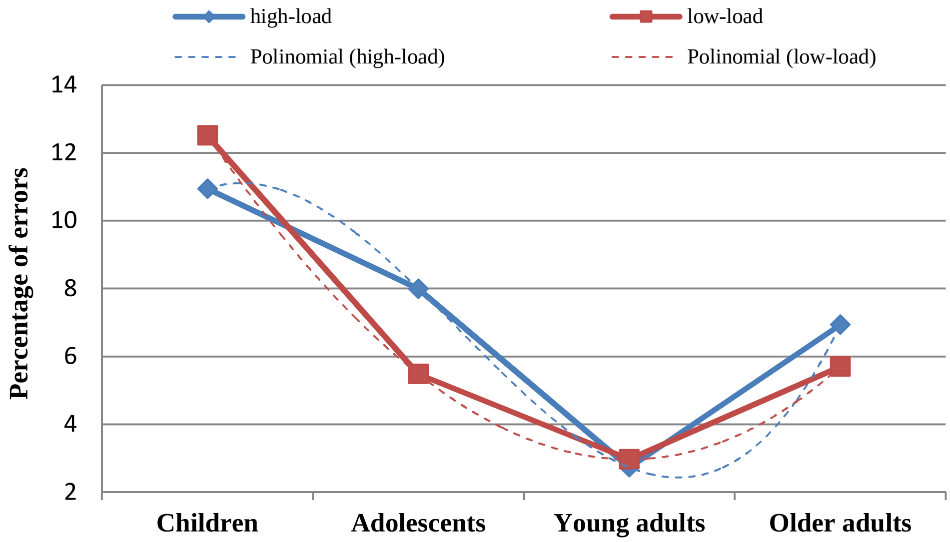


Figure 15. Percentage of errors in the choice reaction time task by age group and by environmental condition. The dashed lines correspond to polynomial trendlines (order 3) for each condition and age group.

Reaction times. Regarding the reaction times to correct responses, both main effects were significant in the mixed ANOVA, $F(1, 252) = 7.76$, $p = .006$, $\eta_p^2 = .030$, for the environment, and $F(3, 252) = 63.34$, $p < .001$, $\eta_p^2 = .430$, for age group. The interaction was non-significant for this variable, $F(3, 252) = 1.03$, $p = .378$, $\eta_p^2 = .012$. Significant differences were found between the older adults and the remaining three age groups ($p < .001$), and between the children and the adolescents ($p = .003$). The remaining multiple comparisons revealed non-significant differences (lowest $p = .275$ for the comparison between children and young adults). An inspection of Figure 16, which presents the developmental perspective of these data, reveal that the older adults were the ones taking the longest to provide correct responses, followed by the children and then by the young adults and the adolescents.

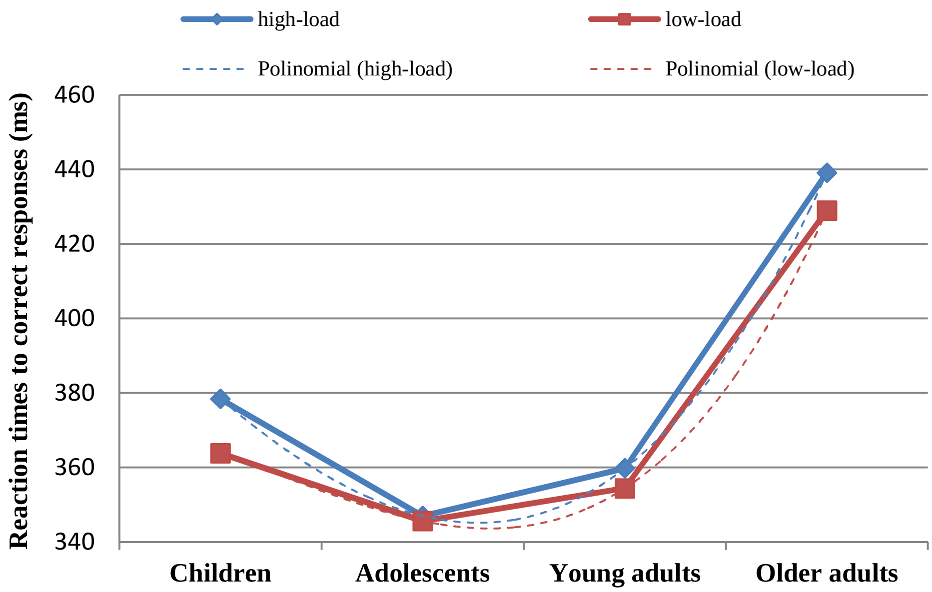


Figure 16. Reaction times for correct responses in the choice reaction time task by age group and by environmental condition. The dashed lines correspond to polynomial trendlines (order 3) for each condition and age group.

Summary of the choice reaction time results. In conclusion, in the choice reaction time task, we also found the expected inverted U-shaped curve for the percentage of correct responses and significant differences among all age groups in the predicted direction; the difference between the adolescents and young adults was close to being significant. Moreover, the effect of the environment was obtained for all groups, with the exception of the young adults as expected. This inverted U-shaped curve is reflected in the trend U-shaped curve for the errors and reaction times; however, an unexpected result was obtained for the adolescents in the last two variables: they committed a similar percentage of errors, but were faster to provide their correct responses than the older adults. Similarly to the go/no-go task, the speed of the adolescents to provide their responses seems to have impaired their performance, because they provided a similar average percentage of errors than the older adults, although an effect of the environment was verified for both groups. The effect of the environment in reaction times was only found for the children.

6.3. Memory tasks

6.3.1. Corsi block-tapping

For the memory span obtained in the Corsi-block tapping task, the main effects of the environment, and of age group were statistically significant, $F(1, 252) = 41.276$, $p < .001$, $\eta_p^2 = .141$, and $F(3, 252) = 42.19$, $p < .001$, $\eta_p^2 = .334$, respectively. Additionally, we found a statistically significant Environment x Age-group interaction, $F(3, 252) = 6.77$, $p < .001$, $\eta_p^2 = .075$. Underlying this interaction are significant effects of the environment in the performance of all age groups, with the exception of the young adults (see Chapters 3-5). The children and the older adults performed significantly worse than the adolescents and the young adults (*ps* < .001). Neither the former nor the later differed between each other (lowest $p = .091$, for the comparison between the children and the older adults). For a graphical illustration of the Corsi block-tapping (memory span) results, see Figure 17.

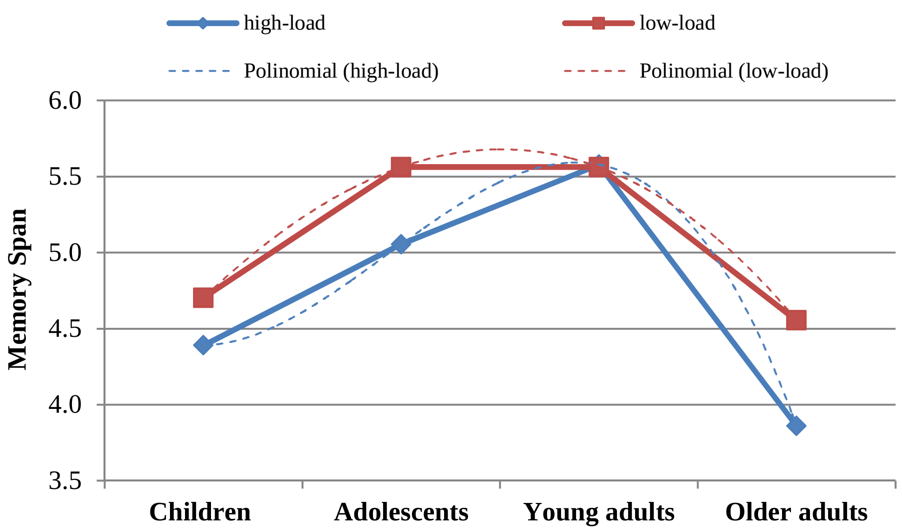


Figure 17. Corsi block-tapping (memory span) by age group and by environmental condition. The dashed lines correspond to polynomial trendlines (order 3) for each condition and age group.

Summary of the Corsi block-tapping results. As mentioned in the introductory chapter, the Corsi block-tapping task is sensitive to capture developmental differences. Our results revealed the predicted inverted U-shaped curve. The older adults and the children obtained the worst performance, followed by the adolescents and the young adults. Even thought we could have expected an advantage of the young adults over the adolescents, their performance did not differ significantly. With exception of the young adults, the high-load environment affected performance in the remaining age groups.

6.3.2. Rey Complex Figure

Regarding this task, we present two variables: copy and memory (3 minutes after) scores. For the *copy*, the main effects of the environment, $F(1, 252) = 5.03$, $p = .026$, $\eta_p^2 = .020$, and of age group, $F(3, 252) = 59.16$, $p < .001$, $\eta_p^2 = .413$, were statistically significant. The interaction Environment x Age-group was non-significant for this variable, $F(3, 252) < 1$. The multiple comparisons among age groups revealed significant differences among them (*ps* < .001), with the exception of the comparison between children and adolescents ($p = .657$) and between adolescents and young adults ($p = .093$); the older participants performed significantly worse than all other age groups. Figure 18 presents graphically the mean scores of this variable by age group and by environment.

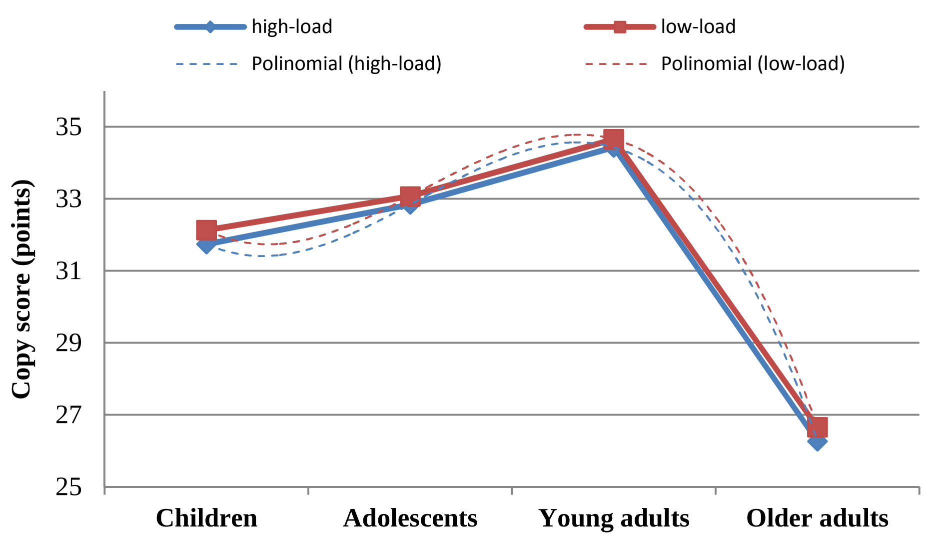


Figure 18. Scores of the Rey Complex Figure – Copy (in points) by age group and by environmental condition. The dashed lines correspond to polynomial trendlines (order 3) for each condition and age group.

For the *immediate memory recall*, the main effects of the environment and of age group were statistically significant, $F(1, 252) = 6.93$, $p = .009$, $\eta_p^2 = .027$, and $F(3, 252) = 71.21$, $p < .001$, $\eta_p^2 = .459$, respectively, as well as the Environment x Age-group interaction, $F(3, 252) = 2.86$, $p = .037$, $\eta_p^2 =.033$. With the exception of the comparison between the adolescents and the young adults ($p > .99$), all multiple comparisons showed significant differences among the performance of all age groups ($p < .001$ for all comparisons). The older adults were the ones with the lowest performance, followed by the children and then by the adolescents and the young adults. Underlying the interaction is a significant effect of the environment in children's performance (see Chapter 3), and the lack of a significant effect for the remaining groups (see Chapters 4-5). The immediate memory scores obtained by age group and by environment are presented in Figure 19.

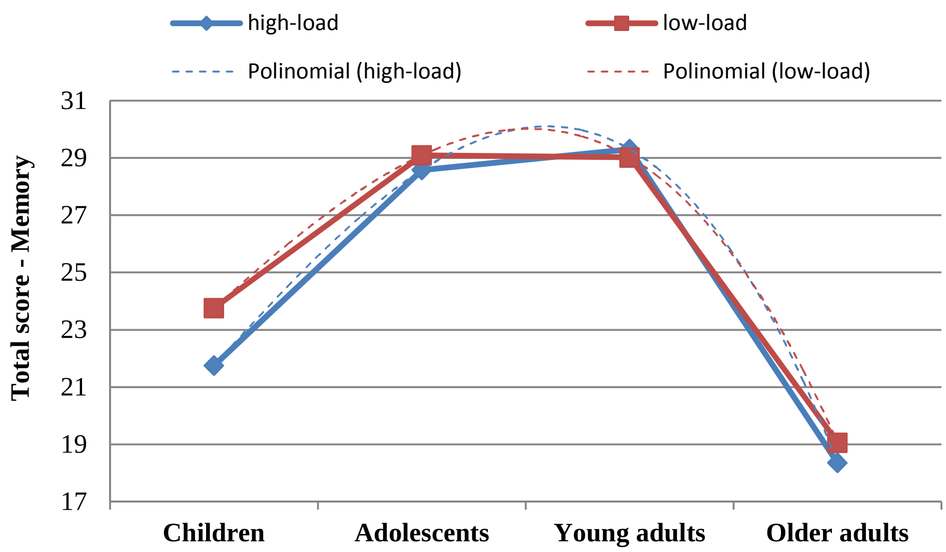


Figure 19. Scores of the Rey Complex Figure – Immediate Recall (in points) by age group and by environmental condition. The dashed lines correspond to polynomial trendlines (order 3) for each condition and age group.

Summary of the Rey Complex Figure results. Regarding the copy performance, considering participants were simply making a copy of the drawing while this was being presented, we expected to obtain no differences between age groups. However, children performed worse than the young adults and no difference was obtained between the later and adolescents who, in turn did not differ significantly from children. This pattern of results might be related to an increased attention to details in the drawing which affect the final score. As for the older adults, who obtained the lowest performance, as noted before, physical difficulties with fine motor movements could underlie this result. While the difference in copy scores was not significant between the children and the adolescents, in the immediate recall a significant difference was found between them. The older adults presented the lowest performance in both variables; again, we can speculate about their typical problems in fine motor. A similar inverted U-shaped curve was also obtained in the immediate recall but now children's performance was significantly worse than that of the adolescents and young adults whose performance did not differ. For this task, an effect of the environment was found only in the immediate recall provided for the children, which underlie the significant Environment x Age-group interaction.

6.4. Concluding remarks

The first aim of this Chapter was to explore if the cognitive performance across the four age groups represented an inverted U-shaped curve (Craik & Bialystok, 2006), when depicting good performance such as correct responses (or the U-shaped curve, when referring to worse performance such as errors). In other words, we expected that the children and the older adults would obtain the lowest performance, followed by the adolescents, whereas the young adults should reveal the best performance. In all variables of the four cognitive tasks, we found significant main effects of age group. In the attentional tasks, the young adults provided the best performance, with the exception of the reaction times to hits (go/no-go) and to correct responses (choice reaction time), and the lowest percentage of false alarms (go/no-go) and of errors (choice reaction time), although some differences were not statistically significant. In both attentional tasks, the adolescents were faster. The children and the older adults presented the lowest performance in all variables as revealed by lower percentage of hits and of correct responses, and slower response times to correct responses. Interestingly, the percentage of false alarms and of errors was larger in children than in the older adults, whereas the last group was the slowest to respond correctly in both attentional tasks. Regarding the adolescents, we expected that they would constitute an intermediate group, that is, with better performance than children and the older adults, but with worse performance than young adults; this result was obtained in the hits (go/no-go), and in the correct responses (choice reaction time task). However, they also provided a higher percentage of errors and of false alarms than the older adults, and were faster than the young adults, although the differences were not significant between the adolescents and the young adults in the reaction times.

Regarding the memory tasks, we also found the expected inverted U-shaped curve, in which the young adults and the adolescents obtained the best performance, followed by the children and then the older adults (Pagulayan et al., 2006; Simões et al., 2011; Yamashita, 2015). As mentioned above, the lowest performance of the older adults in the Rey Complex Figure (copy and immediate recall) and in the Corsi-block tapping was expectable given that they constitute an age group in cognitive deterioration (Craik & Bialystok, 2006; Wais & Gazzaley, 2014).

A statistically significant Environment x Age-group interaction was obtained for all of the reported variables, with the exception of two (reaction times in the choice reaction time task, and for copy score from the Rey Complex Figure). This suggests that, in general, performance of the participants was differently influenced by the environmental manipulation according to their age group. The Environment x Age-group interactions were anticipated because: (1) It was expectable that the four age groups would perform differently among them due to developmental reasons as mentioned in the introductory chapter (Brennan, Bruderer, Liu-Ambrose, Handy, & Enns, 2017; Craik & Bialystok, 2006); (2) Particularly the performance of the children and of the older adults should be particularly impaired by the high-load visual environment (even though due to different motives), given that they are groups with difficulties to filter irrelevant information (in our study, the visual elements in the surrounding environment) (Couperus, 2011; Lavie, 2005; Williams et al., 1999); (3) The adolescents should exhibit a pattern of results more similar to that of young adults as their cognitive capacities are already more developed than that of the children but still not at the top as the young adults. With the exception of the false alarms (go/no-go) and of the errors (choice reaction time task), in which the adolescents obtained a lower performance than the children, in general, the overall performance described the expectable developmental trajectory. Moreover, the environmental effect was obtained in the age groups in which it was expected. The summary of the environmental effects for all variables across all age groups presented in Table 8 provides an easy reading of the results.

In Table 9, we present the results in an alternative perspective: for each age group and variable we counted up the number of participants who obtained the expected result, that is, those that obtained worse performance in the high-load as compared to the low-load visual surrounding environment (e.g., fewer hits and more false alarms in the go/no-go task). Three different counts result from this operation: *plus* – the number of participants whose performance was worse in the high-load visual environment (the result consistent with our initial predictions); *minus* – corresponds to the number of participants whose performance was better in the high-load environment (the opposite of what was initially predicted); *ties* – count of the number of participants whose performance was equal in the two visual environments. Such a presentation provides a more "qualitative" understanding of the data but without considering the magnitude of the difference. Next, we highlight those variables in which the majority (> 55%) of the participants obtained worse performance when tasks were performed in the high-load visual surrounding environment.

In the high-load visual environment, 71.90% of the children provided a lower percentage of hits (go/no-go task), 62.50% of them provided a lower percentage of correct responses, 70.30% were slower to provide their correct responses in the choice reaction time task, and 68.80% performed worse in the immediate recall of the Rey Complex Figure. Regarding the adolescents, 67.19% committed more false alarms in the go/no-go task, 65.60% had fewer correct responses and 56.30% more errors in the choice reaction time task, when responding in high-load visual surrounding environment. As for the older adults, when in this same condition, 62.50% obtained fewer hits and slower reaction times in the go/no-go task; in the choice reaction time task, 65.60% of the older adults provided fewer correct responses, and 67.20% were slower to provide their correct responses; finally, 64.10% of the older adults obtained a lower memory span in the Corsi block-tapping. Importantly, there were no cases in which a majority of participants obtained the opposite of what was expected, that is, worse performance when tasks were conducted in the low-load surrounding environment. Such results illustrate that the surrounding environment can impact peoples' cognitive performance in these tasks, most noticeably in the age groups that are more likely to be more vulnerable to such influence (i.e., older adults and children).

Table 8

Summary of the environmental effects for all variables across all age groups.

	Children	Adolescents	Young adults	Older adults
Go/No-Go				
Hits	✓	✓	-	✓
False alarms	-	✓	-	-
Reaction times	-	-	-	✓
Choice reaction time				
Correct response	✓	✓	-	✓
Errors	-	✓	-	✓
Reaction times	✓	-	-	-
Corsi block-tapping				
Memory span	✓	✓	-	✓
Rey Complex Figure				
Copy	-	-	-	-
Immediate recall	✓	-	-	-

Notes: ✓ The effect of the environment was found; **-** The effect of the environment was not found. A statistically significant Environment*Age-group interaction was obtained for all variables, with the exception of reaction times in the choice reaction time task, and for copy score from the Rey Complex Figure.

Table 9

Summary of the frequency (and proportion) of the pluses, minuses, and ties for all variables for all age groups.

	Children			Adolescents			Young adults			Older adults		
	P	**T**	**M**	**P**	**T**	**M**	**P**	**T**	**M**	**P**	**T**	**M**
Go/No-Go												
Hits	46 (0.72)	2 (0.03)	16 (0.25)	31 (0.48)	12 (0.19)	21 (0.33)	19 (0.30)	31 (0.48)	14 (0.22)	40 (0.63)	0 (0)	24 (0.38)
False alarms	29 (0.45)	5 (0.08)	30 (0.47)	43 (0.67)	2 (0.03)	19 (0.30)	32 (0.50)	13 (0.20)	19 (0.30)	24 (0.38)	15 (0.23)	25 (0.39)
Reaction times	33 (0.52)	-	31 (0.48)	35 (0.55)	-	29 (0.45)	34 (0.53)	-	30 (0.47)	40 (0.63)	-	24 (0.38)
Choice reaction time												
Correct response	40 (0.63)	2 (0.03)	22 (0.34)	42 (0.66)	3 (0.05)	19 (0.30)	32 (0.50)	6 (0.09)	26 (0.41)	42 (0.66)	1 (0.02)	21 (0.33)
Errors	25 (0.39)	4 (0.06)	35 (0.55)	36 (0.56)	3 (0.05)	25 (0.39)	28 (0.44)	12 (0.19)	24 (0.38)	31 (0.48)	7 (0.11)	26 (0.41)
Reaction times	45 (0.70)	-	19 (0.30)	34 (0.53)	-	30 (0.47)	36 (0.56)	-	27 (0.42)	43 (0.67)	-	21 (0.33)
Corsi block-tapping												
Memory span	32 (0.50)	18 (0.28)	14 (0.22)	34 (0.53)	20 (0.31)	10 (0.16)	23 (0.36)	15 (0.23)	26 (0.41)	41 (0.64)	12 (0.19)	11 (0.17)
Rey Complex Figure												
Copy	22 (0.34)	22 (0.34)	20 (0.31)	25 (0.39)	21 (0.33)	18 (0.28)	14 (0.22)	36 (0.56)	14 (0.22)	22 (0.34)	24 (0.38)	18 (0.28)
Immediate recall	44 (0.69)	6 (0.09)	14 (0.22)	34 (0.53)	8 (0.13)	22 (0.34)	22 (0.34)	22 (0.34)	20 (0.31)	30 (0.47)	16 (0.25)	18 (0.28)

Notes: P = Plus: number of participants whose performance was worse in the high-load visual environment; M = Minus: corresponds to the number of participants whose performance was better in the high-load environment; T = Ties: number count of participants whose performance was equal in the two visual environments.

CHAPTER 7.

The influence of the visual surrounding environment on cognitive performance after controlling for anxiety, depression, and chronotype

7.1. Brief introduction

As mentioned in the introductory chapter of this thesis, several individual variables can influence cognitive performance, such as state-anxiety, depression, and chronotype, just to mention a few (Derakshan et al., 2009; Desseilles et al., 2009; Fabbri et al., 2017; Kizilbash et al., 2002; Lapointe et al., 2013; Schmidt et al., 2007; Scult et al., 2016; Vives, López-Navarro, García-Campayo, & Gili, 2015). In this project, even though these three variables (state-anxiety, depression, and chronotype) were not directly manipulated, they were assessed using self-report instruments. The aim of this Chapter was to explore if the environmental effects described in Chapters 3-6 for each age group differed when each of these variables were considered. These should be considered as exploratory only due to procedural concerns noted below.

Before presenting a summary of these exploratory data, some notes about the analyses are firstly presented:

1) We provide analyses for each individual variable (state-anxiety, depression, and chronotype) and for each of the different dependent variables of each cognitive task;

2) For each individual variable (state-anxiety, depression, and chronotype), we used different self-report instruments according to each age group (see details in Chapter 2), although we tried to use instruments across the age groups that assessed similar constructs. Given that each instrument presents different score ranges we conducted the analysis for each age group separately. This form of presentation of the data is also more consistent with the organization adopted in this thesis by age group (Chapters 3-5);

3) State-anxiety was measured in the two sessions (high-load and low-load visual surrounding environments). However, given that no significant differences existed between the two moments (lowest $p = .220$, for the children's group), we considered the average of the two sessions as one single variable;

4) The influence of the visual surrounding environment (high- *vs.* low-load environment; within-subjects factor) in each dependent variable from each cognitive task was analyzed while controlling for anxiety and depression (covariate) using analyses of covariance (ANCOVAs). When significant interactions between the environment and the covariate were found (Environment x Anxiety or Environment x Depression), the results were further explored as follows. First, we calculated the

difference between the two environments creating a measure of the "effect of the environment" for the specific dependent variable involved in the interaction; this effect corresponds to the performance in the high-load *MINUS* the performance in the low-load. Then, we conducted Pearson correlations between this "effect of the environment" and the covariate involved in the interaction [a similar statistical procedure was used by Heathcote et al. (2016)]. For example, if an Environment x Anxiety interaction was found for the percentage of hits provided by children, firstly we calculated the difference between the hits obtained in the two environments (high-load – low-load), and then correlated this difference with the state-anxiety score;

5) The instruments used to assess chronotype allowed us to categorize each participant as morning-, intermediate-, or evening-type, considering the cut-off points defined for each age range and for each of the instrument used (see a description of all instruments in Chapter 2). Then, we classified the period of the day in which each participant performed the tasks. Of note, each participant performed the two experimental sessions at about the same period of day (see details of the Methodology in Chapter 2). According to the time periods usually associated to each chronotype, the sessions that occurred until 11:00 a.m. were considered morning sessions; those that occurred ≥11.00 a.m. and <3:00 p.m. were considered intermediate sessions, whereas those that were performed ≥3:00 p.m. were classified as evening sessions (Horne, Brass, & Petitt, 1980). Finally, we matched the chronotype of the participants (as assessed via the self-report instruments) with the time classification of their sessions. Two groups were created within each age group: the *synchrony-chronotype group* including the individuals for whom the period of the session was coincident with the best performing period of the individual (e.g., a morning-type participant performed the tasks in the morning period), and the *asynchrony-chronotype group* which included the cases in which the moment of the session was not coincident with the best performing period of the individual (e.g., a morning-type participant performed the tasks in the evening period). The influence of the surrounding environment (high- *vs.* low-load; within-subjects factor) and chronotype-group (synchrony- *vs.* asynchrony-chronotype; between-subjects factor) in each dependent variable from each cognitive measure were analyzed using mixed analysis of variance (ANOVAs).

Firstly, we present the results regarding state-anxiety, then depression, and finally chronotype reporting in detail only in those cases where statistical significance was obtained. As noted above, when interactions (Environment x Anxiety or Environment x Depression) were found, we conducted Pearson correlations between the "environmental effect" of the dependent variable and the covariate (state-anxiety or depression) in order to understand how the environmental effect varied according to anxiety or depression scores. We anticipated that the environmental effect would be larger in the participants with higher levels of anxiety and depression, given that they are likely to be more susceptible to visual distraction, that is, they have usually more difficulty to inhibit irrelevant stimuli (e.g., Desseilles et al., 2009; Lapointe et al., 2013). We also expected that the participants from the asynchrony-chronotype group would present a larger environmental effect than those of the synchrony-chronotype group (e.g., Fabbri et al., 2017). For each variable we provide a table summarizing the results. Specifically, in the case of state-anxiety and depression, we indicate whether the main effect of the Environment was statistically significant while controlling for the covariate, and whether the Environment x Covariate was significant. For easiness of comparison with the data obtained in the analyses without the covariates, we also provide the summary of these results in the last column of each table. A similar representation was adopted for the data regarding the chronotype.

7.2. The effect of the visual surrounding environment on cognitive performance after controlling for state-anxiety

Go/no-go: The main effect of the visual surrounding environment in the percentage of hits was maintained in the children and the adolescents after controlling for state-anxiety (highest p = .031, for the adolescents). For these two age groups, we also obtained statistically significant Environment x Anxiety interactions (highest p = .032, for the children). Pearson correlations between the effect of the environment and the state-anxiety scores showed that children with higher anxiety tended to obtain a smaller environmental effect in the percentage of hits than those with lower anxiety (i.e., the high-load visual surrounding environment was more detrimental for the less anxious children; r = .268, p = .032), whereas the adolescents presented an opposite pattern of results (r = -.337, p = .007).

The main effect of the environment in the percentage of false alarms was no longer statistically significant for the adolescents after controlling for anxiety (p = .098), but an Environment x Anxiety interaction was found (p = .017). The Pearson correlation suggested that adolescents with higher levels of anxiety tended to have a higher environmental effect in the percentage of false alarms than those with lower levels of anxiety (i.e., the difference in the percentage of the false alarms between the high- and low-load visual surrounding environment was larger for the more anxious adolescents; $r = .298$, $p = .017$), although no main effect of the environment was found.

Regarding the reaction times for the hits, the environmental effect obtained in the older adults was retained ($p = .003$). See Table 10 for a summary of the obtained results.

Table 10

Summary of the environmental effect (after and before controlling for Anxiety) and interactions (Environment x Anxiety) for all variables from the go/no-go task for each age group.

	Main effect of the environment# (after controlling for Anxiety)	Interaction (Environment x Anxiety)#	Environmental effect§ (without controlling for Anxiety)
HITS			
Children	✓**	✓*	✓***
Adolescents	✓*	✓**	✓**
Young adults	-	-	-
Older adults	-	-	✓**
FALSE ALARMS			
Children	-	-	-
Adolescents	-	✓*	✓***
Young adults	-	-	-
Older adults	-	-	-
REACTION TIMES			
Children	-	-	-
Adolescents	-	-	-
Young adults	-	-	-
Older adults	✓**	-	✓**

Notes: **#** Results obtained from the ANCOVAs; **§** Environmental effects reported in Chapters 3-6; ✓ A significant effect was found; **-** The effect was not statistically significant; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

<u>*Choice reaction time task:*</u> The environmental effect in the percentage of correct responses was maintained only in the older adults after controlling for anxiety ($p = .022$). No Environment x Anxiety interactions were found for this dependent variable.

The main effect of the environment in the percentage of errors was also maintained in the older adults and in the adolescents after controlling for anxiety (highest p = .046, for the older adults). An Environment x Anxiety interaction was also found for the adolescents (p = .012); the follow-up Pearson correlation suggested that the adolescents with higher levels of anxiety had a larger environmental effect in the percentage of errors than those with lower levels of anxiety (i.e., the difference in the percentage of the errors between the high- and low-load visual environment was larger for the more anxious adolescents; r = .311, p = .012), suggesting that they are more susceptible to the detrimental effect of the high-load visual surrounding environment.

For the reaction times, the main effect of the environment found in the children (Chapter 3) was no longer statistically significant after controlling for anxiety (p = .839). Table 11 presents a summary of the obtained results.

Table 11

Summary of the environmental effect (after and before controlling for Anxiety) and interactions (Environment x Anxiety) for all variables from the choice reaction time task for each age group.

	Main effect of the environment# (after controlling for Anxiety)	Interaction (Environment x Anxiety)#	Environmental effect§ (without controlling for Anxiety)
CORRECT RESPONSES			
Children	-	-	✓*
Adolescents	-	-	✓**
Young adults	-	-	-
Older adults	✓*	-	✓***
ERRORS			
Children	-	-	-
Adolescents	✓*	✓*	✓**
Young adults	-	-	-
Older adults	✓*	-	✓*
REACTION TIMES			
Children	-	-	✓*
Adolescents	-	-	-
Young adults	-	-	-
Older adults	-	-	-

Notes: **#** Results obtained from the ANCOVAs; **§** Environmental effects reported in Chapters 3-6; ✓ A significant effect was found; **-** The effect was not statistically significant; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

Memory tasks: After controlling for anxiety, the environmental effect on the *Corsi span* was obtained only in the older adults (*p* = .001). An Environment x Anxiety interaction was obtained for the adolescents (*p* = .043); the Pearson correlation indicated that the adolescents with higher levels of anxiety had larger environmental effect on this dependent variable than the adolescents with lower levels of anxiety (*r* = -.254, *p* = .043). As mentioned in Chapter 6, for the *Rey Complex Figure* we only obtained an environmental effect in the immediate recall of the children, which was lost after controlling for anxiety (*p* = .436). In Table 12 we present a summary of these results.

Table 12

Summary of the environmental effect (after and before controlling for Anxiety) and interactions (Environment x Anxiety) for all variables from the memory tasks for each age group.

	Main effect of the environment# (after controlling for Anxiety)	Interaction (Environment x Anxiety)#	Environmental effect§ (without controlling for Anxiety)
CORSI			
Children	-	-	✓**
Adolescents	-	✓*	✓***
Young adults	-	-	-
Older adults	✓**	-	✓***
FIGURE REY_Copy			
Children	-	-	-
Adolescents	-	-	-
Young adults	-	-	-
Older adults	-	-	-
FIGURE REY_Immediate recall			
Children	-	-	✓**
Adolescents	-	-	-
Young adults	-	-	-
Older adults	-	-	-

Notes: **#** Results obtained from the ANCOVAs; **§** Environmental effects reported in Chapters 3-6; ✓ A significant effect was found; **-** The effect was not statistically significant; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

7.3. The effect of the visual surrounding environment on cognitive performance after controlling for depression

Go/no-go: The environmental effect in the percentage of hits provided by children and adolescents remained significant, after controlling for depression (highest $p = .003$ for the children). However, this effect was no longer significant for the older adults ($p = .233$). For the adolescents, we also found a significant Environment x Depression interaction ($p = .006$). The follow-up Pearson correlation revealed that the adolescents with higher levels of depression are associated to a smaller environmental effect in the percentage of hits than those with lower levels of depression (i.e., the difference in the percentage of hits between the high- and the low-load visual environment was larger for the less depressed adolescents; $r = .339$, $p = .006$).

The main effect of the environment in the percentage of false alarms provided by adolescents was observed after controlling for depression ($p < .001$), but a significant Environment x Depression interaction was also found ($p < .001$). The follow-up Pearson correlation suggested that the adolescents with lower levels of depression had a larger environmental effect than the more depressed adolescents ($r = -.440$, $p < .001$).

The main effect of the environment on the reaction times to correct responses of the older adults was maintained after controlling for depression ($p = .026$). See Table 13 for a summary of the results concerning these analyses.

Table 13

Summary of the environmental effect (after and before controlling for Depression) and interactions (Environment x Depression) for all variables from the go/no-go task for each age group.

	Main effect of the environment[#] (after controlling for Depression)	Interaction (Environment x Depression)[#]	Environmental effect[§] (without controlling for Depression)
HITS			
Children	✓**	-	✓***
Adolescents	✓***	✓**	✓**
Young adults	-	-	-
Older adults	-	-	✓**
FALSE ALARMS			
Children	-	-	-
Adolescents	✓***	✓***	✓***
Young adults	-	-	-
Older adults	-	-	-
REACTION TIMES			
Children	-	-	-
Adolescents	-	-	-
Young adults	-	-	-
Older adults	✓*	-	✓**

Notes: **#** Results obtained from the ANCOVAs; **§** Environmental effects reported in Chapters 3-6; ✓ A significant effect was found; **-** The effect was not statistically significant; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

<u>*Choice reaction time:*</u> The effect of the environment in the percentage of correct responses remained statistically significant in the adolescents ($p < .001$), but a significant Environment x Depression interaction was also found ($p = .027$). The Pearson correlation suggested that the adolescents with lower levels of depression were associated to higher environmental effect than the more depressed adolescents (i.e., the difference in the percentage of the correct responses between the high- and low-load environment was larger for the less depressed adolescents; $r = .277$, $p = .027$).

For the errors, the effect of the environment was still statistically significant in the adolescents and the older adults after controlling for depression ($p < .001$, and $p = .037$, respectively). For the adolescents, we also found an Environment x Depression interaction ($p < .001$): the adolescents with higher levels of depression had a lower environmental effect in the percentage of errors than the adolescents less depressed (*r* = -.448, *p* < .001).

Regarding the reaction times for the correct responses, after controlling for depression, the environmental effect in the children was no longer statistically significant (*p* = .219). An Environment x Depression interaction was obtained for the adolescents (*p* = .009); for these, higher levels of depression tended to have a larger environmental effect (*r* = .322, *p* = .009). See Table 14 for a summary of these results.

Table 14

Summary of the environmental effect (after and before controlling for Depression) and interactions (Environment x Depression) for all variables from the choice reaction time for each age group.

	Main effect of the environment# (after controlling for Depression)	Interaction (Environment x Depression)#	Environmental effect§ (without controlling for Depression)
CORRECT RESPONSES			
Children	-	-	✓*
Adolescents	✓***	✓*	✓**
Young adults	-	-	-
Older adults	-	-	✓***
ERRORS			
Children	-	-	-
Adolescents	✓***	✓***	✓**
Young adults	-	-	-
Older adults	✓*	-	✓*
REACTION TIMES			
Children	-	-	✓*
Adolescents	-	✓**	-
Young adults	-	-	-
Older adults	-	-	-

Notes: **#** Results obtained from the ANCOVAs; **§** Environmental effects reported in Chapters 3-6; ✓ A significant effect was found; **-** The effect was not statistically significant; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

<u>*Memory tasks:*</u> For the <u>*Corsi span*</u>, the statistically significant environmental effect remained for the adolescents and the older adults (highest *p* = .004, for the older adults), after controlling for depression. The environmental effect found in immediate

recall (<u>*Rey Complex Figure*</u>) provided by children was found after controlling for depression (p = .034). Table 15 presents a summary of these results.

Table 15

Summary of the environmental effect (after and before controlling for Depression) and interactions (Environment x Depression) for all variables from the memory tasks for each age group.

	Main effect of the environment# (after controlling for Depression)	Interaction (Environment x Depression)#	Environmental effect§ (without controlling for Depression)
CORSI			
Children	-	-	✓**
Adolescents	✓***	-	✓***
Young adults	-	-	-
Older adults	✓**	-	✓***
FIGURE REY_Copy			
Children	-	-	-
Adolescents	-	-	-
Young adults	-	-	-
Older adults	-	-	-
FIGURE REY_Immediate recall			
Children	✓*	-	✓**
Adolescents	-	-	-
Young adults	-	-	-
Older adults	-	-	-

Notes: **#** Results obtained from the ANCOVAs; **§** Environmental effects reported in Chapters 3-6; ✓ A significant effect was found; **-** The effect was not statistically significant; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

7.4. The effect of the visual surrounding environment on cognitive performance considering synchrony- *vs*. asynchrony-chronotype groups

<u>*Go/no-go:*</u> The main effect of the environment in the percentage of hits remained statistically significant for the children and adolescents considering the two chronotype groups (synchrony *vs*. asynchrony) (p = .001, for both age groups).

Regarding the false alarms provided by adolescents, the main effect of the environment was sustained, even when considering the two chronotype groups ($p < .001$). An Environment x Chronotype interaction was found for the young adults; although no main effect of the environment was found for this age group, the difference in performance between the two environments was higher in the synchrony group, that is, these participants obtained more false alarms in the low-load than in the high-load environment; the opposite pattern of results was obtained for the asynchrony group.

The main effect of the environment in the reaction times for hits of the older adults was still statistically significant when considering the two chronotype groups as a between-subjects factor ($p = .034$). See Table 16 for a summary of the environmental effects and interactions (Environment x Chronotype).

Table 16

Summary of the environmental effect (with and without chronotype groups) and interactions (Environment x Chronotype) for all variables from the go/no-go task for each age group.

	Main effect of the environment# (considering chronotype groups)	Interaction (Environment x Chronotype)#	Environmental effect§ (without chronotype groups)
HITS			
Children	✓**	-	✓***
Adolescents	✓**	-	✓**
Young adults	-	-	-
Older adults	-	-	✓**
FALSE ALARMS			
Children	-	-	-
Adolescents	✓***	-	✓***
Young adults	-	✓**	-
Older adults	-	-	-
REACTION TIMES			
Children	-	-	-
Adolescents	-	-	-
Young adults	-	-	-
Older adults	✓*	-	✓**

Notes: **#** Results obtained from the ANOVAs; **§** Environmental effects reported in Chapters 3-6; ✓ A significant effect was found; **-** The effect was not statistically significant; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

<u>*Choice reaction time:*</u> Considering the two chronotype groups, the significant main effects of the environment in the percentage of correct responses provided by children, adolescents, and older adults were maintained (highest p = .008, for the children). The main effect of the environment in the percentage of errors provided by adolescents was significant (p = .002). Environment x Chronotype interactions were found for the adolescents (p = .042) and for the older adults (p = .036). In the former group, the environmental effect was larger in the synchrony-chronotype group than in the asynchrony-chronotype group. Regarding the older adults, the environmental effect was larger in the asynchrony group, in which they provided a higher percentage of errors in the high-load environment, whereas in the synchrony group the higher percentage of errors was obtained in the low-load environment. Considering the two chronotype groups, the main effect of the environment in the reaction times of the children disappeared (p = .099). See Table 17 for a summary of the results.

Table 17

Summary of the environmental effect (with and without chronotype groups) and interactions (Environment x Chronotype) for all variables from the choice reaction time for each age group.

	Main effect of the environment# (considering chronotypes)	Interaction (Environment x Chronotype)#	Environmental effect§ (without chronotype groups)
CORRECT RESPONSES			
Children	✓**	-	✓*
Adolescents	✓**	-	✓**
Young adults	-	-	-
Older adults	✓**	-	✓***
ERRORS			
Children	-	-	-
Adolescents	✓**	✓*	✓**
Young adults	-	-	-
Older adults	-	✓*	✓*
REACTION TIMES			
Children	-	-	✓*
Adolescents	-	-	-
Young adults	-	-	-
Older adults	-	-	-

Notes: **#** Results obtained from the ANOVAs; **§** Environmental effects reported in Chapters 3-6; ✓ A significant effect was found; **-** The effect was not statistically significant; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

Memory tasks: The statistically significant environmental effects reported in Chapters 3-6 were maintained for the Corsi Span (highest p = .009, for the children) and for the Rey Complex Figure (p = .009). In Table 18, we provide a summary these results.

Table 18

Summary of the environmental effect (with and without chronotype) and interactions (Environment x Chronotype) for all variables from the memory tasks for each age group.

	Main effect of the environment# (considering chronotype groups)	Interaction (Environment x Chronotype)#	Environmental effect§ (without chronotype groups)
CORSI			
Children	✓**	-	✓**
Adolescents	✓***	-	✓***
Young adults	-	-	-
Older adults	✓***	-	✓***
FIGURE REY_Copy			
Children	-	-	-
Adolescents	-	-	-
Young adults	-	-	-
Older adults	-	-	-
FIGURE REY_Immediate recall			
Children	✓*	-	✓**
Adolescents	-	-	-
Young adults	-	-	-
Older adults	-	-	-

Notes: **#** Results obtained from the ANOVAs; **§** Environmental effects reported in Chapters 3-6; ✓ A significant effect was found; **-** The effect was not statistically significant; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

7.5. Concluding remarks

After controlling for anxiety, some of the significant environmental effects reported in Chapters 3-6 disappeared, although some Environment x Anxiety interactions were also found. We expected that individuals with higher levels of anxiety would present a larger environmental effect than those with lower anxiety (e.g., Lapointe et al., 2013; Shackman et al., 2006). Such a result occurred in all of the significant interactions obtained for the adolescents; for example, more anxious adolescents obtained a larger environmental effect in the hits and the false alarms of the go/no-go task, the errors from the choice reaction task and the Corsi blocks, denoting a more detrimental effect of the high-load visual surrounding environment for these individuals. On the other hand, the opposite pattern was obtained for the hits (go/no-go) in children for whom higher levels of anxiety were associated with a smaller environmental effect.

As for depression, we anticipated that participants with higher levels of depression would present a larger environmental effect (e.g., Desseilles et al., 2009; Vijayakumar et al., 2016). However, significant interactions were found in adolescents only and, for the most part, these reflected the opposite of was predicted; specifically, the effect of the environment was smaller for those individuals with higher levels of depression for the hits and false alarms of the go/no-go task, for the correct responses and errors of the choice reaction task; the opposite occurred only for the response times to correct responses of the choice reaction task.

When we considered the chronotype variable, we predicted that individuals who performed the tasks in their best period of the day (the synchrony-chronotype group) would be less affected by the environment as compared to those who did the tasks in their non-optimal period (the asynchrony-chronotype group) (e.g., Fabbri et al., 2017; Schmidt et al., 2007). The results revealed that the environmental effect in the hits (go/no-go) and in the errors (choice reaction time) disappeared for the older adults, as did the environmental effect in the reaction times of the children in the choice reaction time. The remaining environmental effects remained significant. The interactions found between Environment and Chronotype revealed mixed results; for instance, the environmental effect was larger in the errors provided by the adolescents of the synchrony group, but for the older adults the environmental effect was larger in the asynchrony group (the last result was expectable).

These exploratory analyses aimed to scan if the environmental effects differed when each of the three variables were considered, taking into account their typical influence on cognitive performance. However, no firm conclusions should be drawn from these results for several reasons. For instance, in the chronotype groups, we were unable to ensure the correct counterbalancing neither of the order of the environmental manipulation nor of the tasks, two aspects we consider to be important in this type of studies (e.g., Bialystok, Craik, & Luk, 2008; Rodrigues & Pandeirada, 2015). Also in the chronotype groups, we obtained strongly unbalanced groups for each circadian group; for instance, in the older adults, thirteen of the participants performed the tasks during a period that was consistent with their best performing time (i.e., the synchrony-group), whereas fifty-one participated at a period that was not coincident to their best performing period (i.e., the asynchrony-group). Furthermore, in the specific cases of state-anxiety and depression, for the most part, we did not obtain enough variability in the participants' scores that allow us to provide strict conclusions and some of the score were very low. Just to give an example, considering the cut-off points defined for each age group (see detailed information about each instrument in Chapter 2), in the depression instruments, sixty-three children had a non-clinical score and only one obtained a clinical classification. Regarding the adolescents, sixty-one participants could be classified as non-clinical and only three as depressed individuals; fifty-eight young adults could be classified as non-clinical and only six as clinical; thirty-two older adults could be classified as clinical and the remaining thirty-two as non-clinical participants. The descriptive values obtained in each age group (Means and SDs) for each variable, are provided in Appendix 7 along with the score range of each instrument as well as the corresponding cut-off values. Also, we are unable to ensure that the counterbalancing versions are balanced across the individuals varying in these variables.

In conclusion, the results reported in this Chapter should be seen only as exploratory and no firm conclusions should be drawn. Considering the relevance of these variables to cognition, future studies should manipulate them intentionally while adopting correct procedural measures. For example, the groups contrasting on these variables and with an adequate variability should be created *a priori* and then, have each group participate in the experimental sessions while balancing the counterbalancing versions in each group (e.g., Hahn et al., 2012). Such procedure would also allow more conventional statistical analysis than the ones we were able to employ here, particularly for the variables of state-anxiety and depression.

CHAPTER 8.

General Discussion

In everyday life, humans are continuously surrounded by physical environments that can influence their cognition and behavior (Barrett et al., 2015; Colombo, Laddaga, & Antonietti, 2015; Devlin & Andrade, 2017; Fisher et al., 2014; Gifford, 2007; Hart & Moore, 1973; Rodrigues & Pandeirada, 2015). Given that humans have a limited cognitive capacity, several cognitive processes such as selective attention, inhibition, and working memory, allow them to select the important information from the environment while inhibiting irrelevant stimuli (Couperus, 2011; Gaspar et al., 2016; Gazzaley & Nobre, 2012; Lavie, 2010; Squire et al., 2013; Zhou et al., 2016). A large number of studies has explored these cognitive processes using different tasks (specifically with visuo-spatial information) in different age groups (Chadick et al., 2014; McAvinue et al., 2012; Sander et al., 2012; Smith, Jamadar, Provost, & Michie, 2013). Nonetheless, as we indicated throughout this thesis, the vast majority of studies uses a procedure in which targets and distractors are presented in the same visual display (e.g., on the computer screen: Lavie, 2005; Lavie, 2010; Peverill et al., 2016; Tan et al., 2015), neglecting the potential effect of the surrounding environment/real world, thus limiting their ecological validity, as stressed by several authors (e.g., Choi et al., 2014). The central aim of the project here presented was to contribute to the understanding of how cognitive processes operate in conditions that more closely resemble those we face in our everyday life, while using controlled procedures that are typically used in laboratorial settings. Specifically, we aimed to test the influence of visual elements (i.e., irrelevant information for a given task) in cognitive performance (assessed by simple cognitive tasks) when these were embedded in the surrounding environment. This study also contributed to fill a gap identified by several environmental psychologists (e.g., Cassidy, 2013; Gifford, 2007), as noted below.

Environmental psychologists have acknowledged that laboratory research has been very important to understand cognitive functioning, but that, at the same time, can *per se* be a “reductionist” (Cassidy, 2013, p. 16) method, because it usually ignores the real world/natural setting in which individuals are inserted. These authors have argued that cognitive researchers should do an effort to promote ecological validity of their studies to better understand human cognitive and behavioral functioning (Cassidy, 2013; Gifford, 2007; Hart & Moore, 1973).

Although our research was not carried out in “purely” natural settings, we aimed to add a more ecological approach to the cognitive tasks typically administered. Specifically, we manipulated the potential for distraction by embedding visual elements in the surrounding environment (rather than on the same screen where tasks would be performed). We reasoned that this procedure would still allow us to test inhibition, response selection, and working memory for visuo-spatial information in a setting closer to that faces in everyday life. Furthermore, we were interested in exploring if this manipulation of the environment would influence performance in a similar manner at different developmental stages. Cognitive abilities, including selection and inhibition change throughout human development, typically describing an inverted U-shaped curve (e.g., correct responses) or an U-shaped curve (e.g., errors or false alarms) (Brockmole & Logie, 2013; Craik & Bialystok, 2006; Sander et al., 2012; Zelazo et al., 2004). Indeed, cognitive abilities are in maturation in childhood, continuing to develop in adolescence, reach its peak in adulthood, and are in decline during older ages (Brennan et al., 2017; Craik & Bialystok, 2006; Sander et al., 2012). We predicted that our environmental manipulation would interfere negatively with cognitive performance in the opposite manner: to become less disrupting from early ages until early adulthood and, again, its detrimental effect would increase as age progressed. Our participants belonged to four age groups: children, adolescents, young adults, and older adults. Each participant performed two individual sessions: one in a high-load and the other in a low-load visual surrounding environment. In each session, each participant performed four visuo-spatial cognitive tasks: two attentional and two memory tasks. Additionally, some questionnaires were also applied to collect data regarding state-anxiety, depression, and chronotype for further exploratory analysis.

From a developmental point of view, our overall analyses of the data revealed a main effect of the age group in all of the considered variables (Chapter 6), corroborating age-related differences in cognitive performance (Craik & Bialystok, 2006; Sander et al., 2012; Swanson, 2017; Zelazo et al., 2004). Overall, the young adults and the adolescents obtained the best performance, followed by children and the older adults. In the hits, correct responses, Corsi span, and Rey Complex Figure the age-related differences described an inverted U-shaped curve, as expected (Bonifácio et al., 2003; Dykiert et al., 2012; Fernando et al., 2003; Pagulayan et al., 2006; Sander et al., 2012; Simões et al, 2011; Yamashita, 2015). On the other hand, we obtained a U-shaped curve in the remaining variables (i.e., reaction times, errors, and false alarms), a finding that is also in line with previous developmental studies (e.g., Brennan et al., 2017; Casey, Tottenham, Liston, & Durston, 2005; Couperus, 2011; Craik & Bialystok, 2006; Konrad et al., 2013; Rodrigues, 2016; Vidal et al., 2012), although some differences between age groups did not reveal statistical significance. Curiously, adolescents revealed a trend to provide their responses faster than the young adults, a result that refutes developmental studies in which young adults are usually faster to provide their responses than adolescents (e.g., Vidal et al., 2012).

When we analyzed the effects of age group and environment, for the variables of hits (go/no-go) and correct responses (choice reaction time), we found a main effect of the environment and an Environment x Age-group interaction. Underlying the significant interactions are the environmental effects in children, adolescents, and older adults, but not in young-adults. The cognitive performance of the former three age-groups was impaired when they performed the tasks in the high-load as compared with the low-load visual surrounding environment. The results of the older adults are in line with our previous study which followed a similar paradigm (Rodrigues & Pandeirada, 2015): the older adults obtained a lower percentage of hits when they performed a visual go/no-go task in a high-load visual condition, as compared with a low-load visual condition. As in typical cognitive tasks in which targets and distractors are presented in the same display (Gaspelin et al., 2015; Lavie, 2005, 2010), in this paradigm in which distractors were displayed in the surrounding environment, these groups seem to have difficulties ignoring the environmental elements, and consequently had poorer performance.

Regarding the false alarms from the go/no-go task, a main effect of the environment and the Environment x Age-group interaction were found. The children obtained the highest percentage of false alarms, followed by the adolescents, and then by the young and older adults; the latter two did not differ significantly between them. Underlying the interaction is the environmental effect obtained in the adolescents, reflecting a higher percentage of false alarms in the high-load, as compared with the low-load visual surrounding environment. Regarding the errors obtained in the choice reaction time, a main effect of age group and an Environment x Age-group interaction were also obtained. Causing this interaction is the environmental effect in the adolescents and in the older adults, indicating a harmful effect of the high-load environment (higher percentage of errors), as compared to the low-load visual surrounding environment. For these two cases, we expected that the environmental effects would be observed in children, adolescents, and older adults; in other words, we expected that in the high-load environment these three groups would obtain a higher percentage of false alarms and errors than in the low-load environment. The non-significant effect of the environment on cognitive performance of the young adults was expected because they are in the peak of their cognitive capacities and, thus, would have a good capacity to ignore the irrelevant information (visual elements) presented in the surrounding environment. The non-effect in the children in the two cases was unexpected because this constitutes a group with a (still) immature capacity to ignore distractors (e.g., Gaspelin et al., 2015). The environmental effect in the errors (choice reaction time) provided by older adults was expected, because they correspond to a group with typical cognitive declines, including the capacity to filter irrelevant information (Clapp & Gazzaley, 2012). However, the non-significant effect of the environment in the false alarms provided by older adults was unexpected. Interestingly, the percentage of false alarms (go/no-go) provided by the older adults was close to that obtained by young adults. Given that the go/no-go task requires an alternation of active responses and no-responses, we can ponder whether fine motor problems typically observed in these individuals could justify their low percentage of false alarms (Ehsani, Abdollahi, Mohseni Bandpei, Zahiri, & Jaberzadeh, 2015). Of note, the older adults obtained the lowest percentage of active responses (hits and correct responses), and consequently the highest percentage of omissions in the go/no-go task that was used. Curiously, whereas the percentage of false alarms (go/no-go) provided by the older adults did not differ significantly from that provided by the young adults, the difference between them in the errors of the choice reaction time task was significant. A recent study inspected whether a go/no-go procedure (which requires a response to only one the stimulus) was preferable to a choice reaction time task (which requires a response to every stimuli) in older adults and revealed no compelling reasons for choosing of these tasks (Perea, Devis, Marcet, & Gomes, 2016).

Regarding the reaction times, we only observed an environmental effect in the reaction times for hits in the older adults and in the reaction times for correct responses in the children. We expected that both variables would be impaired not only in the children and older adults, but also in the adolescents (e.g., Craik & Bialystok, 2006; Zelazo et al., 2004).

In the two attentional tasks, in general, performance was impaired by the presence of a high-load visual surrounding environment and this impairment differed according to the age group. Given that distraction is usually measured by the percentage of correct responses in a condition compared with other condition (Kannass & Colombo, 2007), we can argue that the high-load visual surrounding environment tended to be distracting for the children, adolescents, and older adults, as compared with the low-load visual surrounding environment (Chapters 3-6). As expected, young adults, whose cognitive capacity was expected to be at its peak, were not influenced by the high-load visual surrounding environment (Chapter 5-6). One possible explanation for this results is usually applied to the more traditional research in which targets and distractors are presented in the same visual display (e.g., Kim et al., 2007; Lavie, 2010; Vidal et al., 2012): the mature cognitive system of the young adults allows them to select the stimuli that are important to the task at hands and to inhibit irrelevant information. Considering our results, we can speculate that the capacity of our young adults to inhibit irrelevant information was not affected even when the distractors were displayed in the surrounding/external environment. On the other hand, the results from the other three age groups revealed an influence of our environmental manipulations (the high- compared with the low-load visual surrounding environment), particularly in the hits and correct responses. The children and the adolescents, probably because they constitute age groups in which the cognitive system is still under maturation; the older adults possibly because they are already undergoing cognitive decline which affects their selective and inhibition capacities (e.g., Brennan et al., 2017; Craik & Bialystok, 2006).

In the Corsi block-tapping, the statistical results revealed a main effect of the environmental condition, as well as a significant Environment x Age-group interaction. In other words, cognitive performance measured by this task was influenced by the environmental condition but this influence was not the same across age groups. With the exception of the young adults (whose performance was not influenced by our environment manipulation), the remaining age groups had a better performance (higher Corsi span) in the low-load, as compared with the high-load visual surrounding environment (Chapters 3-6). As in the attentional tasks, we can discuss these results in light of the developmental theories. Young adults have their cognitive capacity at its peak, accompanied by a good capacity to inhibit their responses to environmental distractors. On the other hand, cognitive capacities are still under development in the children and adolescents, and declining in older adults. In these three age groups, the propensity to distraction (with the visual elements presented in the surrounding environment) was higher than in the young adults (e.g., Craik & Bialystok, 2006; Lavie, 2005). In our previous study with older adults using other memory tasks (Rodrigues & Pandeirada, 2015), we obtained an environmental effect only in one of the four memory tasks. We speculated this result was due to the different modalities recruited by the stimuli in the task (verbal) and the visual nature of the environmental distractors. In the Corsi-block tapping in which we only used visuo-spatial stimuli, the visual environmental effect in the older adults was strong.

With regard to the Rey Complex Figure, we can discuss two different findings. Firstly, in all age groups, the score obtained in the copy administration was higher than that obtained in the immediate recall. These results are in line with the literature because in the copy administration each participant was instructed to copy the RCF in the presence of the figure-stimulus, whereas in the immediate recall each participant was instructed to reproduce the RCF without the figure-stimulus (Caffarra et al., 2002; Rivera et al., 2015). In other words, the immediate recall requires more memory mechanisms than the copy administration (Rey, 1988). Secondly, we only found an effect of the environmental manipulation in children in the immediate recall task: in the low-load visual surrounding environment, children performed significantly better than in the high-load condition. Considering that this is a paper-and-pencil task in which attention is directed to a visual field (table top) that is less exposed to our high- *vs*. low-load visual surrounding panel which is displayed in front of the participant, the lack of a consistent effect of the environment manipulation might not be particularly surprising.

Selective attention, inhibition, and working memory are important cognitive processes across a wide variety of activities we execute in our everyday life. These are mediated by bottom-up and top-down processing, which are in maturation in young ages and in decline in old ages. For the age groups in which the high-load visual surrounding environment impaired cognitive performance, we can speculate that the top-down processing did not allow them to successfully filter the information that was important for the tasks at hand (Gazzaley & Nobre, 2012; Gilbert & Li, 2013; Rodrigues, 2016; Sobel et al., 2007; Zanto et al., 2011). Interestingly, the results of the variables false alarms, errors, and reaction times did not reveal a pattern that was consistent with our predictions (for instance, the environmental manipulation was significant only in adolescents for the false alarms, whereas for the errors both the adolescents and the older adults were impaired by the high-load environment). The active responses (i.e., hits and correct responses) seem to be a better indicator of distraction in this paradigm. Alternatively, we can speculate if this paradigm is simply not sensitive to detect environmental influences if one relies on the errors, false alarms, or reaction times as dependent variables.

This research followed the more ecological approach of the study by Fisher et al. (2014) with children (M_{age} = 5.37 years), and of our previous study with older adults (Rodrigues & Pandeirada, 2015). However, the current study differs in three major aspects. Firstly, we included four different age groups (children, adolescents, young adults, and older adults). Secondly, we aimed to investigate the effect of a high-load *vs*. low-load visual surrounding environment on cognitive performance as measured by specific cognitive tasks that assess more basic cognitive processes that underlie many of daily activities (such as learning). In the case of Fisher et al. (2014), the goal was to investigate whether a decorated-classroom "can affect children's ability to maintain focused attention during instruction and to learn the lesson content" (p. 1362). In this respect, the current study is closer to that of Rodrigues and Pandeirada, although different tasks were here used and the manipulation of the environment was done in a different manner. A methodological difference should also be mentioned: whereas in the study of Fisher et al. (2014) the first session was always in the sparse-classroom condition, and the order of other conditions was alternated between decorated- and sparse-classroom, in our study the order of the environmental conditions, as well as the order of the cognitive tasks, were counterbalanced across participants within each age group (see Appendix 5). This methodological detail is crucial to avoid the influence of potential confounding variables, such as the effects of order and of fatigue (Brooks, 2012).

We also presented an exploratory set of analyses, in which we investigated if the effect of our environmental manipulation differed when the individual variables of state-anxiety, depression, and chronotype were considered. For the state-anxiety, we found several interactions between the effect of the environment and anxiety in the adolescents, revealing that participants with higher levels of state-anxiety had a larger environmental effect than those with lower levels of state-anxiety. In particular, such outcome was obtained for the hits and false alarms (go/no-go), as well as for the errors (choice reaction time) and the Corsi span. This pattern of results is in line with the literature that suggests that anxious people have a tendency for higher distraction, that is, lower capacity to ignore irrelevant stimuli (in our study, the visual elements embedded in the surrounding environment) (e.g., Lapointe et al., 2013). Curiously, an opposite result was obtained in the hits (go/no-go task) provided by the children. Regarding depression, we also found several interactions for the adolescents; specifically, the adolescents with higher levels depression had a smaller environmental effect in the hits and false alarms of the go/no-go task, and in the correct responses and in the errors of the choice reaction time task. This pattern of results is incongruent with literature (e.g., Desseilles et al., 2009) which indicates that depressed individuals seem to have more susceptibility to distraction. However, as predicted, the effect of the environment tended to be larger in the adolescents with higher depression scores in the reaction times for correct responses (choice reaction time task).

For the chronotype, we only found three interactions: in the false alarms (go/no-go) provided by the young adults, in which the synchrony group had a larger environmental effect; in the errors provided by the adolescents, in which the larger environmental effect was also found in the synchrony group; and in the errors committed by the older adults, in which the environmental effect was larger in the asynchrony group, as predicted (e.g., Schmidt et al., 2007). However, as stressed at the end of Chapter 7, no firm conclusions should be drawn from these exploratory data for several reasons. For instance, in the chronotype groups, we were unable to ensure the correct counterbalancing neither of the order of the environmental manipulation nor of the tasks, two aspects we consider to be important in this type of studies (e.g., Bialystok, Craik, & Luk, 2008; Rodrigues & Pandeirada, 2015). For state-anxiety and depression, for the most part, we did not obtain enough variability in the participants' scores that allow us to provide strict conclusions and the overall scores obtained were quite low. Considering the relevance of the individual variables state-anxiety, depression, and chronotype to cognition (e.g., Desseilles et al., 2009; Fabbri et al., 2017; Lapointe et al., 2013), future studies should manipulate them intentionally while adopting correct procedural measures [e.g., the groups contrasting on these variables and with an adequate variability should be created *a priori* and then, have each group participate in the experimental sessions while balancing the counterbalancing versions in each group; Hahn et al. (2012)].

We believe that work following a more ecological approach, such as the one here presented can inform practical implications with a higher validity. For instance, learning activities by children and adolescents, which are mostly conducted in classrooms that present a high-load visual surrounding environment, can be impaired and their learning gains weakened, particularly when they involve visuo-spatial information. Although Fisher et al. (2014) used younger children, our findings could validate their results: when in a decorated-classroom, learning gains were smaller because the high-load visual environment could have been harmful to more basic cognitive abilities. In older adults, for instance, our results could have interest in the area of (neuro)psychological assessments. Given that these individuals seem to be sensible to the environmental elements, a clinical assessment performed in a high-load visual surrounding environment, particularly when visuo-spatial stimuli are involved could be misleading and, thus any proposed treatment base on that assessment might not be the best for that person (Rodrigues & Pandeirada, 2015). In a more applied context, older adults driving in a road heavily surrounded by visual stimulation can have difficulties in selecting the most important information (specific responses to specific stimuli) and in inhibiting irrelevant information (using computerized road tasks; Salvia et al., 2016). In research settings, our results could have important implications, particularly when collecting data from children, adolescents, and older adults. In other words, the organization of the surrounding environment can impact the results in unnoticed forms and influence the results; this should begin to be a methodological element of concern to researchers.

In our study, we tried to maximize the potential influence of the surrounding environment by presenting stimuli that would be of interest to the participants. To this end, we conducted a pilot-study which enabled us to find, for each age group, a set of stimuli they considered most interesting. Then, stimuli were displayed in a way to make these specific sets more visible to the corresponding group while, at the same time, exposing the participant to other stimuli of less interest to them. We believe, however, that this is a good start for future research that should replicate this experimental paradigm with different environmental manipulations. For example, the level of “distractibility” of the surrounding environment could be manipulated using low, intermediate, and high levels of visual load. This would mimic the type of manipulation of the load of distractors used in the typical studies in which targets and distractors are in the same display (Lavie, 2010). Furthermore, our study focused on visual stimuli and stimuli of other sensorial modalities (e.g., auditory stimuli) could also be explored using our proposed paradigm.

Potential issues with the current study should be considered. We can reflect about a possible ceiling effect (e.g., correct responses) and floor effect (e.g., false alarms) in the case of the young adults which could have limited the potential effect of our manipulation in this age group. Given that we conducted a cross-sectional study and wanted to directly compare performance across all age groups, the tasks were created in a way that would be feasible for all age groups. Our option to administer the same task to all participants was based on other studies (Brockmole & Logie, 2013; Kim et al., 2007). An alternative methodological option in future studies would be to present tasks with different degrees of difficulty according to the age group being tested. This would, however limit the direct comparison among groups but allow a clearer understanding of the effect within each age group. Also, groups naturally differed in sociodemographic characteristics, such as educational level; in Portugal, the vast majority of the young adults has (at least) the 9th school year, but for instance, children aged 8-10 years are still attending the 3rd and 4th school years. We can speculate about the potential influence of this variable in our results and future studies should consider this possibility. However, in cross-sectional studies using such different age groups, it will be very hard (if not impossible) to match participants in the number of school years.

Future studies could also introduce objective measures of “distractibility” that would allow us to better understand how our manipulation of the surrounding environment is affecting performance. An example would be to include a measure of eye movements and fixations (e.g., D'Andrea-Penna, Frank, Heatherton, & Tse, 2017). Video recording of the sessions could also provide relevant information on the effect of the surrounding environment in people’s performance (cf. Fisher et al., 2014).

The outcome of this project suggests that the paradigm presented in this work is a promising one. As noted in our preamble, the need to develop procedures that bring the laboratory closer to real life has been warranted for a long time (Gibson, 1979). This was one of our aims: to provide more ecological validity to the study of distraction by employing distraction in a way that more closely mimics what happens in day life. However, given that little is still known about this procedure and how our environment manipulation influenced the performance on the cognitive tasks we used, more empirical evidence is needed. We see this work as a *starting point* to a series of future studies that should further explore this paradigm.

REFERENCES

Aghaie, B., Rejeh, N., Heravi-Karimooi, M., Ebadi, A., Moradian, S. T., Vaismoradi, M., & Jasper, M. (2014). Effect of nature-based sound therapy on agitation and anxiety in coronary artery bypass graft patients during the weaning of mechanical ventilation: A randomised clinical trial. *International Journal of Nursing Studies, 51*, 526-538. doi: 10.1016/j.ijnurstu.2013.08.003

Aksan, N., Dawson, J. D., Emerson, J. L., Yu, L., Uc, E. Y., Anderson, S. W., & Rizzo, M. (2013). Naturalistic distraction and driving safety in older drivers. *Human Factors, 55*, 841-853. doi: 10.1177/0018720812465769

Al-Ayash, A., Kane, R. T., Smith, D., & Green-Armytage, P. (2016). The influence of color on student emotion, heart rate, and performance in learning environments. *Color Research & Application, 41*, 196-205. doi: 10.1002/col.21949

Almeda, M. V., Scupelli, P., Baker, R. S., Weber, M., & Fisher, A. (2014). *Clustering of design decisions in classroom visual displays.* Paper presented at the Proceedings of the Fourth International Conference on Learning Analytics and Knowledge.

Andrade, C. C., & Devlin, A. S. (2015). Stress reduction in the hospital room: Applying Ulrich's theory of supportive design. *Journal of Environmental Psychology, 41*(Supplement C), 125-134. doi: 10.1016/j.jenvp.2014.12.001

Aronen, E. T., Vuontela, V., Steenari, M. R., Salmi, J., & Carlson, S. (2005). Working memory, psychiatric symptoms, and academic performance at school. *Neurobiology of Learning and Memory, 83*, 33-42. doi: 10.1016/j.nlm.2004.06.010

Austin, M.-P., Mitchell, P., & Goodwin, G. M. (2001). Cognitive deficits in depression. *The British Journal of Psychiatry, 178*, 200-206. doi: 10.1192/bjp.178.3.200

Awh, E., Vogel, E. K., & Oh, S. H. (2006). Interactions between attention and working memory. *Neuroscience, 139*, 201-208. doi: 10.1016/j.neuroscience.2005.08.023

Baddeley, A. (1992). Working memory. *Science, 255*(5044), 556-559. doi: 10.1126/science.1736359

Baddeley, A. (2001). Is working memory still working? *American Psychologist, 56*, 851-864. doi: 10.1037/0003-066X.56.11.851

Baddeley, A. (2010). Working memory. *Current Biology, 20*, R136-R140. doi: 10.1016/j.cub.2009.12.014

Baddeley, A. (2012). Working memory: Theories, models, and controversies. *Annual Review of Psychology, 63*, 1-29. doi: 10.1146/annurev-psych-120710-100422

Baddeley, A., & Hitch, G. J. (1974). Working memory. In G. A. Bower (Ed.), *Recent advances in learning and motivation* (pp. 47-90). New York: Academic Press.

Barrett, D. J. K., Shimozaki, S. S., Jensen, S., & Zobay, O. (2016). Visuospatial working memory mediates inhibitory and facilitatory guidance in preview search. *Journal of Experimental Psychology: Human Perception and Performance*, *42*, 1533-1546. doi: 10.1037/xhp0000239

Barrett, P., & Barrett, L. (2010). The potential of positive places: Senses, brain and spaces. *Intelligent Buildings International, 2,* 218-228. doi: 10.3763/inbi.2010.0042

Barrett, P., Davies, F., Zhang, Y., & Barrett, L. (2015). The impact of classroom design on pupils' learning: Final results of a holistic, multi-level analysis. *Building and Environment*, *89*, 118-133. doi: 10.1016/j.buildenv.2015.02.013

Barrett, P., Davies, F., Zhang, Y., & Barrett, L. (2016). The holistic impact of classroom spaces on learning in specific subjects. *Environment and Behavior, 49*, 425-451. doi: 10.1177/0013916516648735

Barry, P. H. (2008a). An evaluation of the impact of the office environment on productivity. *Facilities, 26*(5/6), 178-195. doi: 10.1108/02632770810864970

Barry, P. H. (2008b). The impact of office comfort on productivity. *Journal of Facilities Management, 6*, 37-51. doi: 10.1108/14725960810847459

Baune, B. T., Fuhr, M., Air, T., & Hering, C. (2014). Neuropsychological functioning in adolescents and young adults with major depressive disorder - A review. *Psychiatry Research, 218*, 261-271. doi: 10.1016/j.psychres.2014.04.052

Bialystok, E., Craik, F., & Luk, G. (2008). Cognitive control and lexical access in younger and older bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*, 859-873. doi: 10.1037/0278-7393.34.4.859

Bitan, T., Cheon, J., Lu, D., Burman, D. D., & Booth, J. R. (2009). Developmental increase in top–down and bottom–up processing in a phonological task: An effective connectivity, fMRI study. *Journal of Cognitive Neuroscience, 21*, 1135-1145. doi: 10.1162/jocn.2009.21065

Bonifácio, V., Cardoso-Pereira, N., & Pires, A. M. (2003). *Aferição do teste da Figura Complexa de Rey numa amostra nacional [Standardization of the Rey Complex Figure test in a nacional sample]*. Paper presented at the Congress of Cognitive Neurosciences, Évora, Portugal.

Brennan, A. A., Bruderer, A. J., Liu-Ambrose, T., Handy, T. C., & Enns, J. T. (2017). Lifespan changes in attention revisited: Everyday visual search. *Canadian Journal of Experimental Psychology, 71*, 160-171. doi: 10.1037/cep0000130

Brickenkamp, R. (2007). *d2, Teste de atenção [d2, Test of Attention]*. Lisboa: CEGOC-TEA.

Brockmole, J. R., & Logie, R. H. (2013). Age-related change in visual working memory: A study of 55,753 participants aged 8–75. *Frontiers in Psychology, 4*, 12. doi: 10.3389/fpsyg.2013.00012

Brooks, J. L. (2012). Counterbalancing for serial order carryover effects in experimental condition orders. *Psychological Methods, 17*, 600-614. doi: 10.1037/a0029310

Brunetti, R., Del Gatto, C., & Delogu, F. (2014). eCorsi: Implementation and testing of the Corsi block-tapping task for digital tablets. *Frontiers in Psychology, 5*, 939. doi: 10.3389/fpsyg.2014.00939

Bullard, J. (2016). *Creating environments for learning: Birth to age eight*. Upper Saddle River, New Jersey: Pearson.

Burggraaf, R., Frens, M. A., Hooge, I. T. C., & van der Geest, J. N. (2017). Performance on tasks of visuospatial memory and ability: A cross-sectional study in 330 adolescents aged 11 to 20. *Applied Neuropsychology: Child*, 1-14. doi: 10.1080/21622965.2016.1268960

Buschman, T. J., & Kastner, S. (2015). From behavior to neural dynamics: An integrated theory of attention. *Neuron, 88*, 127-144. doi: 10.1016/j.neuron.2015.09.017

Buschman, T. J., Siegel, M., Roy, J. E., & Miller, E. K. (2011). Neural substrates of cognitive capacity limitations. *Proceedings of the National Academy of Sciences, 108*, 11252-11255. doi: 10.1073/pnas.1104666108

Caffarra, P., Vezzadini, G., Dieci, F., Zonato, F., & Venneri, A. (2002). Rey-Osterrieth Complex Figure: Normative values in an Italian population sample. *Neurological Sciences, 22*, 443-447. doi: 10.1007/s100720200003

Campbell, K. L., Grady, C. L., Ng, C., & Hasher, L. (2012). Age differences in the frontoparietal cognitive control network: Implications for distractibility. *Neuropsychologia, 50*, 2212-2223. doi: 10.1016/j.neuropsychologia.2012.05.025

Carlesimo, G. A., Mauri, M., Graceffa, A. M. S., Fadda, L., Loasses, A., Lorusso, S., & Caltagirone, C. (1998). Memory performances in young, elderly, and very old healthy individuals versus patients with Alzheimer's disease: Evidence for discontinuity between normal and pathological aging. *Journal of Clinical and Experimental Neuropsychology, 20*, 14-29. doi: 10.1076/jcen.20.1.14.1482

Casey, B. J., Tottenham, N., Liston, C., & Durston, S. (2005). Imaging the developing brain: What have we learned about cognitive development? *Trends in Cognitive Sciences, 9*, 104-110. doi: 10.1016/j.tics.2005.01.011

Cassidy, T. (2013). *Environmental psychology: Behaviour and experience in context*. Hove: Psychology Press.

Castaneda, A. E., Tuulio-Henriksson, A., Marttunen, M., Suvisaari, J., & Lönnqvist, J. (2008). A review on cognitive impairments in depressive and anxiety disorders with a focus on young adults. *Journal of Affective Disorders, 106*, 1-27. doi: 10.1016/j.jad.2007.06.006

Chadick, J. Z., Zanto, T. P., & Gazzaley, A. (2014). Structural and functional differences in medial prefrontal cortex underlie distractibility and suppression deficits in ageing. *Nature Communications, 5*, 4223-4250. doi: 10.1038/ncomms5223

Chikazoe, J. (2010). Localizing performance of go/no-go tasks to prefrontal cortical subregions. *Current Opinion in Psychiatry, 23*, 267-272. doi: 10.1097/YCO.0b013e3283387a9f

Choi, H.-H., van Merriënboer, J. J. G., & Paas, F. (2014). Effects of the physical environment on cognitive load and learning: Towards a new model of cognitive load. *Educational Psychology Review, 26*, 225-244. doi: 10.1007/s10648-014-9262-6

Clapp, W. C., & Gazzaley, A. (2012). Distinct mechanisms for the impact of distraction and interruption on working memory in aging. *Neurobiology of Aging, 33*, 134-148. doi: 10.1016/j.neurobiolaging.2010.01.012

Colombo, B., Laddaga, S., & Antonietti, A. (2015). Psychology and design. The influence of the environment's representation over emotion and cognition. An ET study on ikea design. *Procedia Manufacturing, 3*, 2259-2266. doi: 10.1016/j.promfg.2015.07.370

Corsi, P. M. (1972). *Human memory and the medial temporal region of the brain* (PhD thesis). McGill University Montreal, Montreal.

Couperus, J. W. (2011). Perceptual load influences selective attention across development. *Developmental Psychology, 47*, 1431-1439. doi: 10.1037/a0024027

Couto, D. (2011). *Questionário de Cronótipo em Crianças: Adaptação portuguesa do Children’s Chronotype Questionnaire [Portuguese adaptation of the Children ChronoType Questionnaire]* (Master’s thesis). University of Aveiro, Aveiro.

Couto, D., Allen Gomes, A., Pinto de Azevedo, M. H., Bos, S. M. C., Leitão, J. A., & Silva, C. F. (2014). The European Portuguese version of the Children ChronoType Questionnaire (CCTQ): Reliability and raw scores in a large continental sample [P532]. *Journal of Sleep Research*, *23*(s1), 160. doi: 10.1111/jsr.12213/abstract

Craik, F. I., & Bialystok, E. (2006). Cognition through the lifespan: Mechanisms of change. *Trends in Cognitive Sciences, 10*, 131-138. doi: 10.1016/j.tics.2006.01.007

Cuenen, A., Jongen, E. M. M., Brijs, T., Brijs, K., Lutin, M., Van Vlierden, K., & Wets, G. (2015). Does attention capacity moderate the effect of driver distraction in older drivers? *Accident Analysis & Prevention, 77*(Supplement C), 12-20. doi: 10.1016/j.aap.2015.01.011

D'Andrea-Penna, G. M., Frank, S. M., Heatherton, T. F., & Tse, P. U. (2017). Distracting tracking: Interactions between negative emotion and attentional load in multiple-object tracking. *Emotion, 17*, 900-904. doi: 10.1037/emo0000329

Davis, T. R. V. (1984). The influence of the physical environment in offices. *Academy of Management Review, 9*, 271-283. doi: 10.5465/AMR.1984.4277654

Derakshan, N., Smyth, S., & Eysenck, M. W. (2009). Effects of state anxiety on performance using a task-switching paradigm: An investigation of attentional control theory. *Psychonomic Bulletin & Review, 16*, 1112-1117. doi: 10.3758/PBR.16.6.1112

Desseilles, M., Balteau, E., Sterpenich, V., Dang-Vu, T. T., Darsaud, A., Vandewalle, G., . . . Schwartz, S. (2009). Abnormal neural filtering of irrelevant visual information in depression. *The Journal of Neuroscience*, *29*, 1395-1403. doi: 10.1523/jneurosci.3341-08.2009

Devlin, A. S., & Andrade, C. C. (2017). Quality of the hospital experience: Impact of the physical environment. In G. Fleury-Bahi, E. Pol & O. Navarro (Eds.), *Handbook of Environmental Psychology and Quality of Life Research* (pp. 421-440). Cham: Springer International Publishing.

Dias, P., & Gonçalves, M. (1999). Avaliação da ansiedade e da depressão em crianças e adolescentes (STAIC-C2, CMAS-R, FSSC-R e CDI): Estudo normativo para a população portuguesa [Evaluation of anxiety and depression in children and adolescents (STAIC-C2, CMAS-R, FSSC-R and CDI): Normative study for Portuguese population]. In A. P. Soares, S. Araújo & S. Caires (Eds.), *Avaliação Psicológica: Formas e Contextos [Psychological Assessment: Forms and Contexts]* (pp. 553-564). Braga: Apport.

Diette, G. B., Lechtzin, N., Haponik, E., Devrotes, A., & Rubin, H. R. (2003). Distraction therapy with nature sights and sounds reduces pain during flexible bronchoscopy: A complementary approach to routine analgesia. *Chest*, *123*, 941-948. doi: 10.1378/chest.123.3.941

Dorrian, J., McLean, B., Banks, S., & Loetscher, T. (2017). Morningness/eveningness and the synchrony effect for spatial attention. *Accident Analysis & Prevention, 99*, 401-405. doi: 10.1016/j.aap.2015.11.012

Dube, B., Basciano, A., Emrich, S. M., & Al-Aidroos, N. (2016). Visual working memory simultaneously guides facilitation and inhibition during visual search. *Attention, Perception, & Psychophysics, 78*, 1232-1244. doi: 10.3758/s13414-016-1105-8

Dykiert, D., Der, G., Starr, J. M., & Deary, I. J. (2012). Age differences in intra-individual variability in simple and choice reaction time: Systematic review and meta-analysis. *Plos One*, *10*, e45759. doi: 10.1371/journal.pone.0045759

Ehsani, F., Abdollahi, I., Mohseni Bandpei, M. A., Zahiri, N., & Jaberzadeh, S. (2015). Motor learning and movement performance: older versus younger adults. *Basic and Clinical Neuroscience, 6*, 231-238.

Eimer, M. (2014). The neural basis of attentional control in visual search. *Trends in Cognitive Sciences*, *18*, 526-535. doi: 10.1016/j.tics.2014.05.005

Eriksson, J., Vogel, Edward K., Lansner, A., Bergström, F., & Nyberg, L. (2015). Neurocognitive architecture of working memory. *Neuron*, *88*, 33-46. doi: 10.1016/j.neuron.2015.09.020

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion*, *7*, 336-353. doi: 10.1037/1528-3542.7.2.336

Fabbri, M., Frisoni, M., Martoni, M., Tonetti, L., & Natale, V. (2017). Synchrony effect on joint attention. *Experimental Brain Research*, *235*, 2449-2462. doi: 10.1007/s00221-017-4984-6

Fernando, K., Chard, L., Butcher, M., & McKay, C. (2003). Standardisation of the Rey Complex Figure Test in New Zealand children and adolescents. *New Zealand Journal of Psychology, 32,* 33-38.

Fisher, A. V., Godwin, K. E., & Seltman, H. (2014). Visual environment, attention allocation, and learning in young children. *Psychological Science, 25*, 1362-1370. doi: 10.1177/0956797614533801

Forster, S., & Lavie, N. (2011). Entirely irrelevant distractors can capture and captivate attention. *Psychonomic Bulletin & Review, 18*, 1064-1070. doi: 10.3758/s13423-011-0172-z

Freitas, S., Simões, M. R., Alves, L., & Santana, I. (2015). The relevance of sociodemographic and health variables on MMSE normative data. *Applied Neuropsychology: Adult, 22*, 311-319. doi: 10.1080/23279095.2014.926455

Gabrieli, John D. E., & Norton, Elizabeth S. (2012). Reading abilities: Importance of visual-spatial attention. *Current Biology, 22*, R298-R299. doi: 10.1016/j.cub.2012.03.041

Galotti, K. M. (2013). *Cognitive psychology in and out of the laboratory*. Thousand Oaks: Sage.

Gaspar, J. M., Christie, G. J., Prime, D. J., Jolicœur, P., & McDonald, J. J. (2016). Inability to suppress salient distractors predicts low visual working memory capacity. *Proceedings of the National Academy of Sciences*, *113*, 3693-3698. doi: 10.1073/pnas.1523471113

Gaspelin, N., Margett-Jordan, T., & Ruthruff, E. (2015). Susceptible to distraction: Children lack top-down control over spatial attention capture. *Psychonomic Bulletin & Review, 22*, 461-468. doi: 10.3758/s13423-014-0708-0

Gazzaley, A., Clapp, W. C., Kelley, J., McEvoy, K., Knight, R. T., & D' Esposito, M. (2008). Age-related top-down suppression deficit in the early stages of cortical visual memory processing. *Proceedings of the National Academy of Sciences, 105*, 13122-13126. doi: 10.1073/pnas.0806074105

Gazzaley, A., & Nobre, A. C. (2012). Top-down modulation: Bridging selective attention and working memory. *Trends in Cognitive Sciences*, *16*, 129-135. doi: 10.1016/j.tics.2011.11.014

Gibson, J. J. (1979). *The ecological approach to visual perception*. New York: Houghton Mifflin.

Gifford, R. (2007). *Environmental psychology: Principles and practice*. Colville, WA: Optimal Books.

Gilbert, C. D., & Li, W. (2013). Top-down influences on visual processing. *Nature Reviews Neuroscience, 14*, 350-363. doi: 10.1038/nrn3476

Godwin, K. E., Almeda, M. V., Seltman, H., Kai, S., Skerbetz, M. D., Baker, R. S., & Fisher, A. V. (2016). Off-task behavior in elementary school children. *Learning and Instruction, 44*, 128-143. doi: 10.1016/j.learninstruc.2016.04.003

Green, C. T., Bunge, S. A., Briones Chiongbian, V., Barrow, M., & Ferrer, E. (2017). Fluid reasoning predicts future mathematical performance among children and adolescents. *Journal of Experimental Child Psychology, 157,* 125-143. doi: 10.1016/j.jecp.2016.12.005

Guerreiro, M., Silva, A. P., Botelho, A., Leitão, O., Castro-Caldas, A., & Garcia, C. (1994). Adaptação à população portuguesa da tradução do Mini Mental State Examination (MMSE) [Adaptation of the traducted Mini Mental State Examination (MMSE) for Portuguese population]. *Revista Portuguesa de Neurologia, 1,* 9-10.

Gupta, R., Hur, Y. J., & Lavie, N. (2016). Distracted by pleasure: Effects of positive versus negative valence on emotional capture under load. *Emotion, 16,* 328-337. doi: 10.1037/emo0000112

Gutiérrez-García, A. G., & Contreras, C. M. (2013). Anxiety: An adaptive emotion. In F. Durbano (Ed.), *New Insights into Anxiety Disorders* (pp. 21-37). Rijeka: InTech.

Hadwin, J. A., Brogan, J., & Stevenson, J. (2005). State anxiety and working memory in children: A test of processing efficiency theory. *Educational Psychology, 25,* 379-393. doi: 10.1080/01443410500041607

Hahn, C., Cowell, J. M., Wiprzycka, U. J., Goldstein, D., Ralph, M., Hasher, L., & Zelazo, P. D. (2012). Circadian rhythms in executive function during the transition to adolescence: The effect of synchrony between chronotype and time of day. *Developmental Science, 15,* 408-416. doi: 10.1111/j.1467-7687.2012.01137.x

Hart, R. A., & Moore, G. T. (1973). The development of spatial cognition: A review. In R. M. Downs & D. Stea (Eds.), *Image & environment: Cognitive mapping and spatial behavior* (pp. 246-288). New Brunswick, New Jersey: AldineTransaction.

Heathcote, L. C., Koopmans, M., Eccleston, C., Fox, E., Jacobs, K., Wilkinson, N., & Lau, J. Y. F. (2016). Negative interpretation bias and the experience of pain in adolescents. *The Journal of Pain, 17,* 972-981. doi: 10.1016/j.jpain.2016.05.009

Hendriks, G.-J. (2017). Anxiety disorders in later life. In N. A. Pachana (Ed.), *Encyclopedia of Geropsychology* (pp. 276-284). Singapore: Springer Singapore.

Holt, R. J., Graham, J. M., Whitaker, K. J., Hagan, C. C., Ooi, C., Wilkinson, P. O., . . . Suckling, J. (2016). Functional MRI of emotional memory in adolescent depression. *Developmental Cognitive Neuroscience, 19*, 31-41. doi: 10.1016/j.dcn.2015.12.013

Hommel, B., Li, K. Z., & Li, S. C. (2004). Visual search across the life span. *Developmental Psychology, 40*, 545-558. doi: 10.1037/0012-1649.40.4.545

Horne, J. A., Brass, C. G., & Petitt, A. N. (1980). Circadian performance differences between morning and evening 'types'. *Ergonomics, 23*, 29-36. doi: 10.1080/00140138008924715

Horne, J. A., & Östberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International Journal of Chronobiology, 4*, 97-110.

Huisman, E. R. C. M., Morales, E., van Hoof, J., & Kort, H. S. M. (2012). Healing environment: A review of the impact of physical environmental factors on users. *Building and Environment, 58*, 70-80. doi: 10.1016/j.buildenv.2012.06.016

Hunt, R. R., & Einstein, G. O. (1981). Relational and item-specific information in memory. *Journal of Verbal Learning and Verbal Behavior, 20*, 497-514. doi: 10.1016/S0022-5371(81)90138-9

Hwang, K., Velanova, K., & Luna, B. (2010). Strengthening of top-down frontal cognitive control networks underlying the development of inhibitory control: A functional magnetic resonance imaging effective connectivity study. *The Journal of Neuroscience, 30*, 15535-15545. doi: 10.1523/jneurosci.2825-10.2010

Jalil, N. A., Yunus, R. M., & Said, N. S. (2012). Environmental colour impact upon human behaviour: A review. *Procedia - Social and Behavioral Sciences, 35*, 54-62. doi: 10.1016/j.sbspro.2012.02.062

Kannass, K. N., & Colombo, J. (2007). The effects of continuous and intermittent distractors on cognitive performance and attention in preschoolers. *Journal of Cognition and Development, 8*, 63-77. doi: 10.1080/15248370709336993

Katsuki, F., & Constantinidis, C. (2012). Early involvement of prefrontal cortex in visual bottom-up attention. *Nature Neuroscience, 15*, 1160-1166. doi: 10.1038/nn.3164

Kaufman, J. C., & Kaufman, A. S. (2001). Time for the changing of the guard: A farewell to short forms of intelligence tests. *Journal of Psychoeducational Assessment, 19*, 245-267. doi: 10.1177/073428290101900305

Kawashima, R., Satoh, K., Itoh, H., Ono, S., Furumoto, S., Gotoh, R., . . . Fukuda, H. (1996). Functional anatomy of go/no-go discrimination and response selection - A PET study in man. *Brain Research, 728*, 79-89. doi: 10.1016/0006-8993(96)00389-7

Kessels, R. P. C., van den Berg, E., Ruis, C., & Brands, A. M. A. (2008). The backward span of the Corsi block-tapping task and its association with the WAIS-III digit span. *Assessment, 15*, 426-434. doi: 10.1177/1073191108315611

Kessels, R. P. C., van Zandvoort, M. J. E., Postma, A., Kappelle, L. J., & de Haan, E. H. F. (2010). The Corsi block-tapping task: Standardization and normative data. *Applied Neuropsychology, 7*, 252-258. doi: 10.1207/S15324826AN0704_8

Kiehl, K. A., Liddle, P. F., & Hopfinger, J. B. (2000). Error processing and the rostral anterior cingulate: An event-related fMRI study. *Psychophysiology, 37*, 216-223. doi: 10.1111/1469-8986.3720216

Kim, E. Y., Iwaki, N., Imashioya, H., Uno, H., & Fujita, T. (2007). Error-related negativity in a visual go/no-go task: Children vs. adults. *Developmental Neuropsychology, 31*, 181-191. doi: 10.1080/87565640701190775

Kiyonaga, A., & Egner, T. (2013). Working memory as internal attention: Toward an integrative account of internal and external selection processes. *Psychonomic Bulletin & Review, 20*, 228-242. doi: 10.3758/s13423-012-0359-y

Kizilbash, A. H., Vanderploeg, R. D., & Curtiss, G. (2002). The effects of depression and anxiety on memory performance. *Archives of Clinical Neuropsychology, 17*, 57-67. doi: 10.1016/S0887-6177(00)00101-3

Konrad, K., Firk, C., & Uhlhaas, P. J. (2013). Brain development during adolescence: Neuroscientific insights into this developmental period. *Deutsches Ärzteblatt International, 110*, 425-431. doi: 10.3238/arztebl.2013.0425

Konstantinou, N., Beal, E., King, J. R., & Lavie, N. (2014). Working memory load and distraction: Dissociable effects of visual maintenance and cognitive control.

Attention, Perception & Psychophysics, 76, 1985-1997. doi: 10.3758/s13414-014-0742-z

Kovacs, M. (1992). *The Children's Depression Inventory (CDI): Manual*. New York: Multi-Health Systems.

Krampe, R. T. (2002). Aging, expertise and fine motor movement. *Neuroscience & Biobehavioral Reviews, 26*, 769-776. doi: 10.1016/S0149-7634(02)00064-7

Kroll, A., Mak, M., & Samochowiec, J. (2016). Learning to search. The importance of eye movements in the decrease of response times during a visual choice reaction time task. *9*, 1-5. doi: 10.16910/jemr.9.5.5

Kuuskorpi, M., & González, N. C. (2011). *The future of the physical learning environment: School facilities that support the user*. CELE Exchange, Centre for Effective Learning Environments, Paris: OECD Publishing.

Kwallek, N., Soon, K., Woodson, H., & Alexander, J. L. (2005). Effect of color schemes and environmental sensitivity on job satisfaction and perceived performance. *Perceptual and Motor Skills, 101*, 473-486. doi: 10.2466/pms.101.2.473-486

Lapointe, M.-L. B., Blanchette, I., Duclos, M., Langlois, F., Provencher, M. D., & Tremblay, S. (2013). Attentional bias, distractibility and short-term memory in anxiety. *Anxiety, Stress, & Coping, 26*, 293-313. doi: 10.1080/10615806.2012.687722

Lara, A. H., & Wallis, J. D. (2015). The role of prefrontal cortex in working memory: A mini review. *Frontiers in Systems Neuroscience, 9*, 173. doi: 10.3389/fnsys.2015.00173

Lavie, N. (2005). Distracted and confused?: Selective attention under load. *Trends in Cognitive Sciences, 9,* 75-82. doi: 10.1016/j.tics.2004.12.004

Lavie, N. (2010). Attention, distraction, and cognitive control under load. *Current Directions in Psychological Science, 19*, 143-148. doi: 10.1177/0963721410370295

Lavie, N., Hirst, A., De Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General, 133,* 339-354. doi: 10.1037/0096-3445.133.3.339

Leiva, A., Andrés, P., Servera, M., Verbruggen, F., & Parmentier, F. B. R. (2016). The role of age, working memory, and response inhibition in deviance distraction: A cross-sectional study. *Developmental Psychology, 52,* 1381-1393. doi: 10.1037/dev0000163

Levandovski, R., Sasso, E., & Hidalgo, M. P. (2013). Chronotype: A review of the advances, limits and applicability of the main instruments used in the literature to assess human phenotype. *Trends in Psychiatry and Psychotherapy, 35*, 3-11. doi: 10.1590/S2237-60892013000100002

Levin, R. L., Heller, W., Mohanty, A., Herrington, J. D., & Miller, G. A. (2007). Cognitive deficits in depression and functional specificity of regional brain activity. *Cognitive Therapy and Research*, *31*, 211-233. doi: 10.1007/s10608-007-9128-z

Liefooghe, B. (2017). The contribution of task-choice response selection to the switch cost in voluntary task switching. *Acta Psychologica, 178*, 32-40. doi: 10.1016/j.actpsy.2017.05.006

Lockwood, K. A., Alexopoulos, G. S., & van Gorp, W. G. (2002). Executive dysfunction in geriatric depression. *American Journal of Psychiatry*, *159*, 1119-1126. doi: 10.1176/appi.ajp.159.7.1119

López-Samanes, Á., Moreno-Pérez, D., Maté-Muñoz, J. L., Domínguez, R., Pallarés, J. G., Mora-Rodriguez, R., & Ortega, J. F. (2016). Circadian rhythm effect on physical tennis performance in trained male players. *Journal of Sports Sciences*, *35*, 2121-2128. doi: 10.1080/02640414.2016.1258481

Luna, B. (2009). Developmental changes in cognitive control through adolescence. *Advances in Child Development and Behavior*, *37*, 233-278. doi: 10.1016/S0065-2407(09)03706-9

MacLeod, C., & Mathews, A. (2012). Cognitive bias modification approaches to anxiety. *Annual Review of Clinical Psychology, 8*, 189-217. doi: 10.1146/annurev-clinpsy-032511-143052

Madden, D. J., & Langley, L. K. (2003). Age-related changes in selective attention and perceptual load during visual search. *Psychology and Aging*, *18*, 54-67. doi: 10.1037/0882-7974.18.1.54

Martins, A. M. Q. (2000). *As manifestações clínicas da depressão na adolescência [Clinical manifestations of depression in adolescence]*. (Master’s thesis). University of Porto, Porto.

Mastroberardino, S., & Vredeveldt, A. (2014). Eye-closure increases children's memory accuracy for visual material. *Frontiers in Psychology, 5*, 1-6. doi: 10.3389/fpsyg.2014.00241

Matchock, R. L., & Mordkoff, J. T. (2009). Chronotype and time-of-day influences on the alerting, orienting, and executive components of attention. *Experimental Brain Research, 192*, 189-198. doi: 10.1007/s00221-008-1567-6

McAvinue, L. P., Habekost, T., Johnson, K. A., Kyllingsbæk, S., Vangkilde, S., Bundesen, C., & Robertson, I. H. (2012). Sustained attention, attentional selectivity, and attentional capacity across the lifespan. *Attention, Perception, & Psychophysics, 74*, 1570-1582. doi: 10.3758/s13414-012-0352-6

Merrill, E. C., & Conners, F. A. (2013). Age-related interference from irrelevant distracters in visual feature search among heterogeneous distracters. *Journal of Experimental Child Psychology, 115*, 640-654. doi: 10.1016/j.jecp.2013.03.013

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience, 24,* 167-202. doi: 10.1146/annurev.neuro.24.1.167

Morooka, T., Ogino, T., Takeuchi, A., Hanafusa, K., Oka, M., & Ohtsuka, Y. (2012). Relationships between the color-word matching stroop task and the go/no-go task: toward multifaceted assessment of attention and inhibition abilities of children. *Acta Medica Okayama, 66*, 377-386. doi: 10.18926/amo/49385

Mostofsky, S. H., & Simmonds, D. J. (2008). Response inhibition and response selection: Two sides of the same coin. *Journal of Cognitive Neuroscience, 20*, 751-761. doi: 10.1162/jocn.2008.20500

Mueller, S. T. (2012). PEBL: The Psychology Experiment Building Language (Version 0.13). Retrieved from http://pebl.sourceforge.net/.

Mueller, S. T., & Piper, B. J. (2014). The Psychology Experiment Building Language (PEBL) and PEBL Test Battery. *Journal of Neuroscience Methods, 222*, 250-259. doi: 10.1016/j.jneumeth.2013.10.024

Nanda, U., Eisen, S., Zadeh, R. S., & Owen, D. (2011). Effect of visual art on patient anxiety and agitation in a mental health facility and implications for the business case. *Journal of Psychiatric Mental Health Nursing, 18*, 386-393. doi: 10.1111/j.1365-2850.2010.01682.x

Oberauer, K., Farrell, S., Jarrold, C., & Lewandowsky, S. (2016). What limits working memory capacity? *Psychological Bulletin, 142*, 758-799. doi: 10.1037/bul0000046

Olesen, P. J., Macoveanu, J., Tegnér, J., & Klingberg, T. (2007). Brain activity related to working memory and distraction in children and adults. *Cerebral Cortex, 17*, 1047-1054. doi: 10.1093/cercor/bhl014

Oliveira-Brochado, F., Simões, M. R., & Paúl, C. (2014). Inventário de Depressão de Beck (BDI-II) [Beck Depression Inventory (BDI-II)]. In L. S. Almeida, M. R. Simões & M. M. Gonçalves (Eds.), *Instrumentos e contextos de avaliação psicológica [Instruments and contexts of psychological assessment]* (pp. 187-209). Coimbra: Edições Almedina, S. A.

Pagulayan, K. F., Busch, R. M., Medina, K. L., Bartok, J. A., & Krikorian, R. (2006). Developmental normative data for the Corsi Block-tapping task. *Journal of Clinical and Experimental Neuropsychology*, *28*, 1043-1052. doi: 10.1080/13803390500350977

Peelen, M. V., & Kastner, S. (2014). Attention in the real world: Toward understanding its neural basis. *Trends in Cognitive Sciences, 18*, 242-250. doi: 10.1016/j.tics.2014.02.004

Perea, M., Devis, E., Marcet, A., & Gomez, P. (2016). Are go/no-go tasks preferable to two-choice tasks in response time experiments with older adults? *Journal of Cognitive Psychology, 28*, 147-158. doi: 10.1080/20445911.2015.1107077

Peverill, M., McLaughlin, K. A., Finn, A. S., & Sheridan, M. A. (2016). Working memory filtering continues to develop into late adolescence. *Developmental Cognitive Neuroscience, 18*, 78-88. doi: 10.1016/j.dcn.2016.02.004

Pocinho, M. T. S., Farate, C., Dias, C. A., Lee, T. T., & Yesavage, J. A. (2009). Clinical and psychometric validation of the Geriatric Depression Scale (GDS) for

Portuguese elders. *Clinical Gerontologist, 32*, 223-236. doi: 10.1080/07317110802678680

Porter, R. J., Bourke, C., & Gallagher, P. (2007). Neuropsychological impairment in major depression: Its nature, origin and clinical significance. *Australian & New Zealand Journal of Psychiatry, 41*, 115-128. doi: 10.1080/00048670601109881

Preckel, F., Lipnevich, A. A., Schneider, S., & Roberts, R. D. (2011). Chronotype, cognitive abilities, and academic achievement: A meta-analytic investigation. *Learning and Individual Differences, 21*, 483-492. doi: 10.1016/j.lindif.2011.07.003

Raanaas, R. K., Patil, G. G., & Hartig, T. (2010). Effects of an indoor foliage plant intervention on patient well-being during a residential rehabilitation program. *HortScience, 45*, 387-392.

Rae, C. L., Hughes, L. E., Anderson, M. C., & Rowe, J. B. (2015). The prefrontal cortex achieves inhibitory control by facilitating subcortical motor pathway connectivity. *The Journal of Neuroscience, 35*, 786-794. doi: 10.1523/jneurosci.3093-13.2015

Randler, C., Faßl, C., & Kalb, N. (2017). From lark to owl: Developmental changes in morningness-eveningness from new-borns to early adulthood. *Scientific Reports, 7*, 45874. doi: 10.1038/srep45874

Rey, A. (1988). *Teste de Cópia de Figuras Complexas [Rey Complex Figures Test]*. Lisboa: Cegoc.

Ribeiro, Ó., Paúl, C., Simões, M. R., & Firmino, H. (2011). Portuguese version of the Geriatric Anxiety Inventory: Transcultural adaptation and psychometric validation. *Aging & Mental Health, 15*, 742-748. doi: 10.1080/13607863.2011.562177

Rivera, D., Perrin, P. B., Morlett-Paredes, A., Galarza-Del-Angel, J., Martinez, C., Garza, M. T., . . . Arango-Lasprilla, J. C. (2015). Rey-Osterrieth Complex Figure - copy and immediate recall: Normative data for the Latin American Spanish speaking adult population. *NeuroRehabilitation, 37*, 677-698. doi: 10.3233/nre-151285

Rivera, D., Salinas, C., Ramos-Usuga, D., Delgado-Mejía, I., Vasallo Key, Y., Hernandez Agurcia, G., . . . Rabago Barajas, B. (2017). Concentration Endurance

Test (d2): Normative data for Spanish-speaking pediatric population. *NeuroRehabilitation, 41*, 661-671. doi: 10.3233/NRE-172248

Robinson, S. J., & Brewer, G. (2016). Performance on the traditional and the touch screen, tablet versions of the Corsi block and the Tower of Hanoi tasks. *Computers in Human Behavior, 60*, 29-34. doi: 10.1016/j.chb.2016.02.047

Rodrigues, P. F. S. (2012). Alterações mnésicas e atencionais em idosos [Mnesic and attentional changes in older adults]. *Psicologia, Educação e Cultura, 16*, 116-130.

Rodrigues, P. F. S. (2016). Processos cognitivos visuoespaciais e ambiente visual circundante: Implicações educacionais [Visuospatial cognitive processes and visual surrounding environment: Educational implications]. *Psicologia: Teoria e Pesquisa, 32*, 1-10. doi: 10.1590/0102.3772e3244

Rodrigues, P. F. S., & Pandeirada, J. N. S. (2015). Attention and working memory in elderly: The influence of a distracting environment. *Cognitive Processing, 16,* 97-109. doi: 10.1007/s10339-014-0628-y

Rodrigues, P. F. S., & Pandeirada, J. N. S. (2016). *The influence of the visual surrounding environment in cognitive tasks: A study with children*. Poster session presented at the International Meeting of the Psychonomic Society, Granada, Spain.

Rodrigues, P. F. S., Pandeirada, J. N. S., Bem-Haja, P., & França, J. (2017). The Trait Anxiety Scale for Children: A validation study for European Portuguese children and adolescents. *European Journal of Developmental Psychology*, 1-9. doi: 10.1080/17405629.2017.1308249

Rodrigues, P. F. S., Pandeirada, J. N. S., Bem-Haja, P., & França, J. (in press). Assessing state-anxiety in European Portuguese children and adolescents: Adaptation and validation of the State Anxiety Scale for Children. *Measurement and Evaluation in Counseling and Development*.

Rodrigues, P. F. S., Pandeirada, J. N. S., Marinho, P. I., Bem-Haja, P., Silva, C. F., Ribeiro, L., & Fernandes, N. L. (2016). Morningness-eveningness preferences in Portuguese adolescents: Adaptation and psychometric validity of the H&O questionnaire. *Personality and Individual Differences, 88*, 62-65. doi: 10.1016/j.paid.2015.08.048

Roenneberg, T., Kuehnle, T., Pramstaller, P. P., Ricken, J., Havel, M., Guth, A., & Merrow, M. (2004). A marker for the end of adolescence. *Current Biology, 14*, 1038-1039. doi: 10.1016/j.cub.2004.11.039

Rowe, J. B., Toni, I., Josephs, O., Frackowiak, R. S. J., & Passingham, R. E. (2000). The prefrontal cortex: Response selection or maintenance within working memory? *Science, 288*(5471), 1656-1660. doi: 10.1126/science.288.5471.1656

Rubia, K. (2013). Functional brain imaging across development. *European Child & Adolescence Psychiatry, 22*, 719-731. doi: 10.1007/s00787-012-0291-8

Salthouse, T. A. (2009). When does age-related cognitive decline begin? *Neurobiology of Aging, 30*, 507-514. doi: 10.1016/j.neurobiolaging.2008.09.023

Salvia, E., Petit, C., Champely, S., Chomette, R., Di Rienzo, F., & Collet, C. (2016). Effects of age and task load on drivers' response accuracy and reaction time when responding to traffic lights. *Frontiers in Aging Neuroscience, 8*, 169. doi: 10.3389/fnagi.2016.00169

Sander, M. C., Lindenberger, U., & Werkle-Bergner, M. (2012). Lifespan age differences in working memory: A two-component framework. *Neuroscience & Biobehavioral Reviews, 36*, 2007-2033. doi: 10.1016/j.neubiorev.2012.06.004

Santana, I., Duro, D., Lemos, R., Costa, V., Pereira, M., Simões, M. R., & Freitas, S. (2016). Mini-Mental State Examination: Avaliação dos novos dados normativos no rastreio e diagnóstico do défice cognitivo [Mini-Mental State Examination: Evaluation of new normative data in screening and diagnostic of cognitive deficit]. *Acta Médica Portuguesa, 29*, 240-248. doi: 10.20344/amp.6889

Santana, J., & Galera, C. (2014). Visual-spatial and verbal-spatial binding in working memory. *Psychology & Neuroscience, 7*, 399-406. doi: 10.3922/j.psns.2014.048

Schmidt, C., Collette, F., Cajochen, C., & Peigneux, P. (2007). A time to think: Circadian rhythms in human cognition. *Cognitive Neuropsychology, 24*, 755-789. doi: 10.1080/02643290701754158

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime user's guide*. Pittsburgh: Psychology Software Tools.

Schreij, D., Los, S. A., Theeuwes, J., Enns, J. T., & Olivers, C. N. L. (2014). The interaction between stimulus-driven and goal-driven orienting as revealed by eye movements. *Journal of Experimental Psychology: Human Perception and Performance, 40*, 378-390. doi: 10.1037/a0034574

Schrobsdorff, H., Ihrke, M., Behrendt, J., Hasselhorn, M., & Herrmann, J. M. (2012). Inhibition in the dynamics of selective attention: An integrative model for negative priming. *Frontiers in Psychology, 3,* 491-512. doi: 10.3389/fpsyg.2012.00491

Scult, M. A., Paulli, A. R., Mazure, E. S., Moffitt, T. E., Hariri, A. R., & Strauman, T. J. (2016). The association between cognitive function and subsequent depression: A systematic review and meta-analysis. *Psychological Medicine, 47,* 1-17. doi: 10.1017/S0033291716002075

Seidler, R. D., Bernard, J. A., Burutolu, T. B., Fling, B. W., Gordon, M. T., Gwin, J. T., . . . Lipps, D. B. (2010). Motor control and aging: Links to age-related brain structural, functional, and biochemical effects. *Neuroscience & Biobehavioral Reviews, 34*(5), 721-733. doi: 10.1016/j.neubiorev.2009.10.005

Senese, V. P., De Lucia, N., & Conson, M. (2015). Cognitive predictors of copying and drawing from memory of the Rey-Osterrieth Complex Figure in 7- to 10-year-old children. *The Clinical Neuropsychologist, 29*, 118-132. doi: 10.1080/13854046.2014.995711

Shackman, A. J., Sarinopoulos, I., Maxwell, J. S., Pizzagalli, D. A., Lavric, A., & Davidson, R. J. (2006). Anxiety selectively disrupts visuospatial working memory. *Emotion*, *6*, 40-61. doi: 10.1037/1528-3542.6.1.40

Shipstead, Z., Harrison, T. L., & Engle, R. W. (2012). Working memory capacity and visual attention: Top-down and bottom-up guidance. *Quarterly Journal of Experimental Psychology, 65,* 401-407. doi: 10.1080/17470218.2012.655698

Silva, C. F., Silvério, J. M. A., Rodrigues, P. J. F., Pandeirada, J. N. S., Fernandes, S. M., Macedo, F. B., & Razente, S. N. (2002). The Portuguese version of the Horne and Östberg morningness-eveningness questionnaire: Its role in Education and Psychology. *Revista Psicologia e Educação, 1,* 39-50.

Silva, D. R., & Spielberger, C. D. (2007). *Manual do Inventário de Estado Traço de Ansiedade (STAI) [Manual of the State-Trait Anxiety Inventory]*. Published by Mind Garden, Inc.

Simmonds, D. J., Pekar, J. J., & Mostofsky, S. H. (2008). Meta-analysis of go/no-go tasks demonstrating that fMRI activation associated with response inhibition is task-dependent. *Neuropsychologia, 46*, 224-232. doi: 10.1016/j.neuropsychologia.2007.07.015

Simões, M. R., Pinho, M. S., Lopes, A. F., Sousa, L. B., & Lopes, C. A. (2011). Figura Complexa de Rey (Bateria de Avaliação Neuropsicológica de Coimbra-BANC) [Rey Complex Figure (Coimbra Neuropsychological Assessment Battery-BANC)]. In M. G. C. Machado, L. Almeida, & M. R. Simões (Eds.), *Instrumentos e Contextos de Avaliação Psicológica [Instruments and Contexts of Psychological Evaluation]* (pp. 9-44). Coimbra: Edições Almedina, SA.

Smith, J. L., Jamadar, S., Provost, A. L., & Michie, P. T. (2013). Motor and non-motor inhibition in the Go/NoGo task: An ERP and fMRI study. *International Journal of Psychophysiology, 87*, 244-253. doi: 10.1016/j.ijpsycho.2012.07.185

Sobel, K. V., Gerrie, M. P., Poole, B. J., & Kane, M. J. (2007). Individual differences in working memory capacity and visual search: The roles of top-down and bottom-up processing. *Psychonomic Bulletin & Review, 14*, 840-845. doi: 10.3758/BF03194109

Spielberger, C. D., Edwards, C. D., Lushene, R., Monturoi, J., & Platzek, D. (1973). *State-Trait Anxiety Inventory for Children: Sampler set, manual, test booklet, scoring key*. Palo Alto: Mind Garden.

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). Manual for the state-trait anxiety inventory. Palo Alto: Consulting Psychologists Press.

Spronk, M., Vogel, E. K., & Jonkman, L. M. (2012). Electrophysiological evidence for immature processing capacity and filtering in visuospatial working memory in adolescents. *Plos One, 7*, e42262. doi: 10.1371/journal.pone.0042262

Squire, R. F., Noudoost, B., Schafer, R. J., & Moore, T. (2013). Prefrontal contributions to visual selective attention. *Annual Review Neuroscience, 36*, 451-466. doi: 10.1146/annurev-neuro-062111-150439

Steele, V. R., Aharoni, E., Munro, G. E., Calhoun, V. D., Nyalakanti, P., Stevens, M. C., . . . Kiehl, K. A. (2013). A large scale (N=102) functional neuroimaging study of response inhibition in a go/no go task. *Behavioural Brain Research, 256*, 529-536. doi: 10.1016/j.bbr.2013.06.001

Steele, V. R., Claus, E. D., Aharoni, E., Harenski, C., Calhoun, V. D., Pearlson, G., & Kiehl, K. A. (2014). A large scale (N = 102) functional neuroimaging study of error processing in a go/no go task. *Behavioural Brain Research, 268*, 127-138. doi: 10.1016/j.bbr.2014.04.001

Steidle, A., & Werth, L. (2014). In the spotlight: Brightness increases self-awareness and reflective self-regulation. *Journal of Environmental Psychology, 39*, 40-50. doi: 10.1016/j.jenvp.2013.12.007

Stern-Ellran, K., Zilcha-Mano, S., Sebba, R., & Levit Binnun, N. (2016). Disruptive effects of colorful vs. non-colorful play area on structured play-A pilot study with preschoolers. *Frontiers in Psychology, 7*, 1661. doi: 10.3389/fpsyg.2016.01661

Stillman, A. N., Rowe, K. C., Arndt, S., & Moser, D. J. (2012). Anxious symptoms and cognitive function in non-demented elderly adults: An inverse relationship. *International Journal of Geriatric Psychiatry, 27*, 792-798. doi: 10.1002/gps.2785

Swanson, H. L. (2017). Verbal and visual-spatial working memory: What develops over a life span? *Developmental Psychology, 53*, 971-995. doi: 10.1037/dev0000291

Tan, J., Zhao, Y., Wang, L., Tian, X., Cui, Y., Yang, Q., . . . Chen, A. (2015). The competitive influences of perceptual load and working memory guidance on selective attention. *Plos One, 10*, e0129533. doi: 10.1371/journal.pone.0129533

Tanja-Dijkstra, K. (2011). The impact of bedside technology on patients' well-being. *Health Environments Research & Design Journal, 5*, 43-51. doi: 10.1177/193758671100500104

Thayer, J. F., Verkuil, B., Brosschotj, J. F., Kevin, K., West, A., Sterling, C., . . . Sternberg, E. M. (2010). Effects of the physical work environment on physiological measures of stress. *European Journal of Cardiovascular Prevention & Rehabilitation, 17*, 431-439. doi: 10.1097/HJR.0b013e328336923a

Theeuwes, J. (2010). Top–down and bottom–up control of visual selection. *Acta Psychologica, 135*, 77-99. doi: 10.1016/j.actpsy.2010.02.006

Tsubomi, H., & Watanabe, K. (2017). Development of visual working memory and distractor resistance in relation to academic performance. *Journal of Experimental Child Psychology, 154*, 98-112. doi: 10.1016/j.jecp.2016.10.005

Ulrich, R. S., Simons, R. F., & Miles, M. A. (2003). Effects of environmental simulations and television on blood donor stress. *Journal of Architectural and Planning Research, 20*, 38-47.

Ursache, A., & Raver, C. C. (2014). Trait and state anxiety: Relations to executive functioning in an at-risk sample. *Cognition and Emotion, 28*, 845-855. doi: 10.1080/02699931.2013.855173

Valdez, P. (2012). Circadian rhythms in cognitive performance: Implications for neuropsychological assessment. *ChronoPhysiology and Therapy, 2*, 81-92. doi: 10.2147/CPT.S32586

Valdez, P., Ramírez, C., & García, A. (2014). Circadian rhythms in cognitive processes: Implications for school learning. *Mind, Brain, and Education, 8*, 161-168. doi: 10.1111/mbe.12056

Vara, A. S., Pang, E. W., Vidal, J., Anagnostou, E., & Taylor, M. J. (2014). Neural mechanisms of inhibitory control continue to mature in adolescence. *Developmental Cognitive Neuroscience, 10*(Supplement C), 129-139. doi: 10.1016/j.dcn.2014.08.009

Verbruggen, F., & Logan, G. D. (2008a). Automatic and controlled response inhibition: Associative learning in the go/no-go and stop-signal paradigms. *Journal of Experimental Psychology: General, 137*, 649-672. doi: 10.1037/a0013170

Verbruggen, F., & Logan, G. D. (2008b). Response inhibition in the stop-signal paradigm. *Trends in Cognitive Sciences, 12*, 418-424. doi: 10.1016/j.tics.2008.07.005

Vidal, J., Mills, T., Pang, E. W., & Taylor, M. J. (2012). Response inhibition in adults and teenagers: Spatiotemporal differences in the prefrontal cortex. *Brain and Cognition, 79*, 49-59. doi: 10.1016/j.bandc.2011.12.011

Vijayakumar, N., Allen, N. B., Youssef, G., Dennison, M., Yücel, M., Simmons, J. G., & Whittle, S. (2016). Brain development during adolescence: A mixedlongitudinal investigation of cortical thickness, surface area, and volume. *Human Brain Mapping, 37,* 2027-2038. doi: 10.1002/hbm.23154

Vijayakumar, N., Whittle, S., Yücel, M., Byrne, M. L., Schwartz, O., Simmons, J. G., & Allen, N. B. (2016). Impaired maturation of cognitive control in adolescents who develop major depressive disorder. *Journal of Clinical Child & Adolescent Psychology, 45*, 31-43. doi: 10.1080/15374416.2014.987381

Vincent, E., Battisto, D., Grimes, L., & McCubbin, J. (2010). The effects of nature images on pain in a simulated hospital patient room. *HERD: Health Environments Research & Design Journal, 3,* 42-55. doi: 10.1177/193758671000300306

Vischer, J. C. (2007). The effects of the physical environment on job performance: Towards a theoretical model of workspace stress. *Stress and Health, 23*, 175-184. doi: 10.1002/smi.1134

Vives, M., López-Navarro, E., García-Campayo, J., & Gili, M. (2015). Cognitive impairments and depression: A critical review. *Actas Espanolas de Psiquiatria, 43*, 187-193.

Vredeveldt, A., Hitch, G. J., & Baddeley, A. D. (2011). Eye closure helps memory by reducing cognitive load and enhancing visualisation. *Memory & Cognition, 39*, 1253-1263. doi: 10.3758/s13421-011-0098-8

Vuontela, V., Carlson, S., Troberg, A. M., Fontell, T., Simola, P., Saarinen, S., & Aronen, E. T. (2013). Working memory, attention, inhibition, and their relation to adaptive functioning and behavioral/emotional symptoms in school-aged children. *Child Psychiatry & Human Development, 44*, 105-122. doi: 10.1007/s10578-012-0313-2

Vytal, K. E., Cornwell, B. R., Letkiewicz, A. M., Arkin, N. E., & Grillon, C. (2013). The complex interaction between anxiety and cognition: Insight from spatial and verbal working memory. *Frontiers in Human Neuroscience, 7*, 93. doi: 10.3389/fnhum.2013.00093

Wais, P. E., & Gazzaley, A. (2014). External distraction impairs categorization performance in older adults. *Psychology and Aging, 29*, 666-671. doi: 10.1037/a0037617

Wechsler, D. (2003). *WISC-III: Escala de Inteligência de Wechsler para Crianças [WISC-III: Wechsler Intelligence Scale for Children]* (3rd ed.). Lisboa: Cegoc.

Wechsler, D. (2008). *WAIS-III: Escala de Inteligência de Wechsler para Adultos [WAIS-III: Wechsler Adult Intelligence Scale]* (3rd ed.). Lisboa: Cegoc.

Wetherell, J. L., Reynolds, C. A., Gatz, M., & Pedersen, N. L. (2002). Anxiety, cognitive performance, and cognitive decline in normal aging. *The Journals of Gerontology: Series B, 57*, 246-255. doi: 10.1093/geronb/57.3.P246

Williams, B. R., Ponesse, J. S., Schachar, R. J., Logan, G. D., & Tannock, R. (1999). Development of inhibitory control across the life span. *Developmental Psychology*, *35*, 205-213. doi: 10.1037/0012-1649.35.1.205

Woods, D. L., Wyma, J. M., Yund, E. W., Herron, T. J., & Reed, B. (2015). Factors influencing the latency of simple reaction time. *Frontiers in Human Neuroscience, 9,* 131. doi: 10.3389/fnhum.2015.00193

Wu, C.-C., Wick, F., & Pomplun, M. (2014). Guidance of visual attention by semantic information in real-world scenes. *Frontiers in Psychology, 5*, 54 doi: 10.3389/fpsyg.2014.00054

Yamashita, H. (2015). Effects of the immediate recall trial on delayed recall performance in the Rey Complex Figure Test in young and older adults. *Applied Neuropsychology: Adult, 22*, 197-203. doi: 10.1080/23279095.2014.898641

Zanto, T. P., Rubens, M. T., Thangavel, A., & Gazzaley, A. (2011). Causal role of the prefrontal cortex in top-down modulation of visual processing and working memory. *Nature Neuroscience*, *14*, 656-661. doi: 10.1038/nn.2773

Zelazo, P. D., Craik, F. I. M., & Booth, L. (2004). Executive function across the life span. *Acta Psychologica, 115*, 167-183. doi: 10.1016/j.actpsy.2003.12.005

Zhou, X., Zhu, D., King, S. G., Lees, C. J., Bennett, A. J., Salinas, E., . . . Constantinidis, C. (2016). Behavioral response inhibition and maturation of goal representation in prefrontal cortex after puberty. *Proceedings of the National Academy of Sciences, 113,* 3353-3358. doi: 10.1073/pnas.1518147113

Appendix 1

Assessing state-anxiety in European Portuguese children and adolescents: Adaptation and validation of the State Anxiety Scale for Children

| Copy of the accepted version of the Manuscript |

(Rodrigues, Pandeirada, Bem-Haja, & França, in press)

This is the accepted version of the Manuscript for publication by Taylor & Francis in
Measurement and Evaluation in Counseling and Development,
on 29-August-2017 (in press).

Reference:

Rodrigues, P. F. S., Pandeirada, J. N. S., Bem-Haja, P., & França, J. (in press). Assessing state-anxiety in European Portuguese children and adolescents: Adaptation and validation of the State Anxiety Scale for Children. *Measurement and Evaluation in Counseling and Development*.

Assessing state-anxiety in European Portuguese children and adolescents: Adaptation and validation of the State Anxiety Scale for Children

Pedro F. S. Rodrigues[a,b*], Josefa N. S. Pandeirada[a,c*], Pedro Bem-Haja[a,b*], and Joana França[d]

[a]Department of Education and Psychology, University of Aveiro, Campus Universitário de Santiago, Aveiro, Portugal; [b]IBILI, University of Coimbra, Coimbra, Portugal; [c]CINTESIS.UA, Aveiro, Portugal; [d]Câmara Municipal de Estarreja, Estarreja, Portugal

Abstract

We present an initial validation of the State Anxiety Scale for Children for Portuguese children and adolescents. No significant differences were found between sexes and among school cycle groups. The data revealed good psychometric properties and the ‘anxiety-absent’ and ‘anxiety-present’ factors were confirmed. Potential applications of the instrument are presented.

Keywords: State Anxiety Scale for Children (SASC), European Portuguese children, European Portuguese adolescents, Psychometric properties, Confirmatory Factor Analysis

[*] The first three authors have contributed equally to this work and share first authorship in the paper. *Corresponding author:* Josefa N. S. Pandeirada ✉ josefa@ua.pt

Introduction

Anxiety is an emotion with adaptive functions that typically includes cognitive, physiological and behavioral manifestations. However, when this emotional response is excessive it becomes a pathological condition (Beesdo, Knappe, & Pine, 2009). Particularly in children and adolescents, anxiety disorders have negative impact in various areas such as in cognitive and academic performance, and in social life (e.g., Mazzone et al., 2007; Settipani & Kendall, 2013). Furthermore, this type of disorder is amongst the most frequent psychopathologies in young ages and is related to a higher probability of experiencing anxiety problems later in adulthood (Merikangas, Nakamura, & Kessler, 2009), as well as of suffering from other pathologies such as depression or substance abuse (Wu et al., 2010). Understanding the anxiety reactions of children and adolescents in their everyday lives is crucial to help them deal with those situations, to prevent the development of clinical conditions, and to avoid the negative consequences these might have. Using appropriate instruments that allow a reliable assessment of anxiety states is essential to achieve these goals.

The State-Trait Anxiety Inventory for Children (STAIC; Spielberger, Edwards, Lushene, Monturoi, & Platzek, 1973) is one of the most used instruments to assess anxiety in children and adolescents (Seligman, Ollendick, Langley, & Baldacci, 2004). This self-report questionnaire includes two scales that separately assess the state- and the trait-anxiety. The first refers to a transitory emotional reaction to a real or potential stressful event or stimuli, whereas the second refers to a more stable tendency to experience anxiety and is often described as an individual difference (Spielberger et al., 1973). In this work, we focused our attention in the state scale of STAIC, hereafter designated by State Anxiety Scale for Children (SASC).

The SASC has been frequently used in research and in clinical settings. Specifically, it has been used to assess the anxiety consequences of certain life events such as the death of a parent (e.g., Raveis, Siegel, & Karus, 1999) or having to face medical procedures (e.g., Li & Lopez, 2004). The psychological adjustment to specific treatments has also been tracked with this scale (e.g., Wechsler & Sánchez-Iglesias, 2013). Studies exploring the relation between state-anxiety, cognitive performance (e.g., Hadwin, Brogan, & Stevenson, 2005), and other areas of performance (e.g., musical performance; Ryan, 2004; anxiety when performing sport and nonsport activities; Simon & Martens, 1979) have also used it. Although other instruments exist to assess the anxiety experienced in specific situations (e.g., Children's Fear Survey Schedule-Dental Subscale; Beena, 2013), the SASC is a worldwide used scale in a large variety of domains.

The SASC is composed of 20 items, 10 of which formulated to capture the absence of anxiety and the remaining 10 to capture its presence. The former correspond to the “anxiety-absent” factor and the later to the “anxiety-present” factor, according to studies that have explored the factorial structure of this scale (e.g., Dorr, 1981; Hedl & Papay, 1982). This same factorial structure has been obtained consistently in validation studies across the world (e.g., Li & Lopez, 2004; Psychountaki, Zervas, Karteroliotis, & Spielberger, 2003). Although the SASC was originally designed to measure anxiety in children aged 9-12 years (Spielberger et al., 1973), it can be used with younger and older children. Indeed, several validation studies have obtained good psychometric properties for the scale using other age ranges (e.g., 7-12Y-old, Li & Lopez, 2004; 9-15Y-old, Spielberger, Edwards, Lushene, Monturoi, & Platzek, 2009).

The popularity of this instrument has motivated researchers from around the world to adapt it for their own populations. As stressed by various authors, instruments should be adapted for the culture where they will be used, because some items or concepts may be appropriate in a given culture, but not in another (e.g., Beaton, Bombardier, Guillemin, & Ferraz, 2000). The SASC has been translated and adapted into languages such as Brazilian Portuguese (Biaggio, 1980), Chinese (Li & Lopez, 2004), Greek (Psychountaki et al., 2003), and Spanish (Gómez-Fernández & Spielberger, 1990), just to name a few. Overall, the validation studies have reported good internal consistency as measured by Cronbach’s α (e.g., 84-.85, Li & Lopez, 2004; 82-.87, Spielberger et al., 1973) and good test-retest reliability (e.g., .78-.79; Li & Lopez, 2004).

Some of these validation studies have also explored sex differences on state-anxiety motivated by the fact that females tend to develop higher anxiety levels than males. However, the results have been inconsistent with some studies reporting a tendency for higher anxiety in males than in females (e.g., Spielberger et al., 1973), others reporting the opposite pattern (Gómez-Fernández & Spielberger, 1990), and still others reporting no difference between sexes (e.g., Psychountaki et al., 2003).

Another variable that has been considered in the study of state-anxiety and that has also provided mixed results is age. For example, Psychountaki et al. (2003) obtained a significant effect of the academic year (strongly related to age) on state-anxiety:

Participants attending the fourth grade reported significantly less anxiety than those attending the fifth grade who, in turn, indicated less anxiety than the participants from the sixth grade (not significant). However, Day, Knight-II, El-Nakad, and Spielberger (1986) found no influence of grade level on state-anxiety.

Given the overarching importance of assessing state-anxiety, the aims of this study were to translate and adapt the SASC for European Portuguese children and adolescents, to provide its preliminary psychometric proprieties, to test its factorial structure and to present other validity indicators. A previous study has been conducted in Portugal to adapt and validate this instrument. In this study conducted by Matias (2004) , during the adaptation process, 10 new items were added to the original scale, resulting in an instrument that differs somewhat from the original. Additionally, no Confirmatory Factor Analysis (CFA) was conducted in that work. Finally, Mind Garden (owner of the copyrights of the instrument) informed us of the inexistence of a European Portuguese version of this scale. The present study is also justified by the potential applicability of this instrument as just reviewed. To fulfill our aims, we conducted the typical translation procedures from the original instrument and applied the resulting version to a group of children and adolescents in two different moments in time. We also asked participants to report the presence of any stressors in the two administration moments. We provide information on the reliability of the scale, as evaluated by its internal consistency (Cronbach's α), and temporal constancy (test-retest reliability) by calculating the Intraclass Correlation Coefficient (ICC). The factorial structure was tested via a CFA using several indexes (cf. data analysis section). The state-anxiety values reported by participants who experienced a stressful event in only one of the moments were considered to provide preliminary evidence of the construct validity of the data (Li & Lopez, 2004). We predicted that state-anxiety would be higher when a stressor was occurring as compared to when it was absent. Additionally, we explored the differences between sexes and among school cycle groups; Considering that the school cycles are naturally related with age, the later analysis provides information on the relation between age and anxiety. We do not provide specific predictions for these results given the inconsistencies in the literature.

Method

Participants

The sample included 405 participants aged 8-14 years (M_{age} = 11.41, *SD* = 1.87): 202 females (M_{age} = 11.52, *SD* = 1.87) and 203 males (M_{age} = 11.30, *SD* = 1.86). Participants were recruited from 7 schools of the Aveiro district and were attending three different school cycles. According to the Portuguese education system, the first cycle includes grades 1-4, the second cycle includes grades 5 and 6, and the third cycle includes grades 7-9. In our sample, the group from the first school cycle included students attending the third and fourth grades (N = 100; 24.7% of the full sample; M_{age} = 8.87; *SD* = 0.69). The group from the second school cycle included students from grades five and six (N = 78; 19.3% of the full sample; M_{age} = 10.49; *SD* = 0.73). Finally, the group from the third school cycle included students attending the seventh and eighth grades (N = 227; 56.0% of the full sample; M_{age} = 12.85; *SD* = 0.79). Six other participants were excluded because they turned 15 years during the study (N = 2) or did not complete the two phases of the data collection (N = 4). Schools were selected by convenience but, in an effort to increase the representativeness of our sample regarding different educational environments, we included public and private schools, as well as schools from rural and urban areas. The study was authorized by the Portuguese Directorate-General for Education and by the school directors. Only students with previous informed consent from their parents and who agreed to participate voluntarily took part in the study.

Instrument

The *SASC* is one of the independent scales of the STAIC (Spielberger et al., 1973) that assesses the level of anxiety individuals are experiencing at the exact moment they are responding to the instrument. It includes 20 items and responses are provided by choosing one of three options that describe how the participant is feeling at that moment. Most studies argue for a two-factor scale. The “anxiety-absent” factor includes items that are formulated to capture the absence of anxiety (e.g., item 1: “I’m feeling…”[©] with the response options “very calm”, “calm” or “not calm”; items 1, 3, 6, 8, 10, 12, 13, 14, 17, and 20); the lowest, intermediate and highest severity of the symptom are scored with 1, 2, and 3 points, respectively. The remaining 10 items of the scale compose the “anxiety-present” factor and are formulated to indicate the presence of anxiety (e.g., item 4: “I’m feeling…”© with the response options “very nervous”, “nervous” or “not nervous”); these are scored in the opposite manner. The total score ranges from 20 (minimal anxiety) to 60 points (highest anxiety).

The translation of the SASC into European Portuguese included the following four phases: 1) translation of the original questionnaire into European Portuguese by two Portuguese researchers highly proficient in English; 2) re-translation of our translated form of the scale into English by a bilingual English Professor naïve to the original version; and, 3) examination of the translated and re-translated versions by two researchers and one clinical psychologist to adjust some of the terms considering our age sample. Finally, in order to ensure the content validity of the instrument, a think-aloud protocol was implemented with 15 participants (9 males) aged 8-13 years (M_{age} = 9.87; *SD* = 2.26) in group sessions of 2-3 participants. This last procedure led to additional wording adjustments to ensure the instrument was adequate. For example, the word “troubled” translates directly to “perturbado”, a term not easily understood by our children; To allow clarification of the term we added the expression “muito agitado” [*very agitated*] which was used by participants during the think-aloud procedure. During the entire process of adaptation and validation of the instrument, we complied with all the formal requirements imposed by Mind Garden, Inc, owner of the copyrights of the instrument.

Procedure

The scale was administered in groups of 12-28 participants under the supervision of one of the authors in sessions lasting approximately 15-20 minutes (the SASC was included in a battery of instruments administered to each group of participants; according the aims of this paper, we only report the data from the SASC). This same procedure was repeated 3-4 weeks later for the retest assessment. In both sessions, after completing the questionnaires, participants were asked to indicate (written response) any recent event that worried them or any stressful event they were still experiencing.

Data Analysis

The factorial validity of the instrument was assessed through CFA using the Weighted Least Squares with Mean and Variance adjustment (WLSMV; Finney &

diStefano, 2006); These analyses were conducted using M-Plus 7.4 (Muthén & Muthén, 2012). This estimator relied on the polychoric correlation matrix given the categorical nature of the scale (Lorenzo-Seva & Ferrando, 2014). The overall goodness-of-fit of the factor model was evaluated using the following indexes: χ^2; Comparative Fit Index (CFI); Parsimony Comparative Fit Index (PCFI); Tucker Lewis Index (TLI); Root Mean Square Error of Approximation (RMSEA); P[rmsea $\leq$ 0.05]; Akaike Information Criterion (AIC); and, Weighted Root Mean Square (WRMR). For each index, we considered the cut-off points for "good adjustment" as defined by Marôco (2014, p.51; see note in Table 1). Sex invariance was tested using the χ^2 difference test for categorical variables. These analyses were also conducted using M-Plus 7.4 (Muthén & Muthén, 2012). The local adjustment was estimated by the factor weights and individual reliability of the items. The Composite Reliability and Average Variance Extracted (AVE; Convergent and Discriminant Validity) for each factor were evaluated as described by Fornell and Larcker (1981). In reliability analysis, the internal consistency was evaluated by Cronbach's α and the temporal constancy (test-retest reliability) by the Intraclass Correlation Coefficient (ICC).

An independent samples *t*-test and one-way ANOVA were used to evaluate the relationship of sex and school cycle in SASC totals, respectively (two-tailed significance level, $p < .05$). We also explored if sex influenced the results on each factor considering that the two-factor structure was confirmed for the two sexes (repeated-measures ANOVA). The difference in state-anxiety considering the presence/absence of a stressor was calculated using a paired *t*-test. These analyses were carried out with IBM SPSS (v.22).

Results

Construct Validity

The construct validity was evaluated by considering the factorial, the convergent and the discriminant validities. Regarding the factorial validity, we compared different factorial solutions using CFA with the WLSMV estimator and a polychoric matrix. We started by considering a one-factor solution given the initial formulation of the instrument. Then, following the theoretical developments and previous empirical demonstrations we tested the two-factor model (e.g., Dorr, 1981; Psychountaki et al., 2003). The former revealed poor goodness-of-fit indexes, whereas the latter obtained good goodness-of-fit indexes (see Table 1 for the indexes obtained with these solutions). Regarding the WRMR, even though both models exceed the recommended value, the two-factor solution obtained a lower value than the one-factor solution, indicating that less variance would be left unexplained by the two-factor model. Also, according to the AIC index, the two-factor model provides the most parsimonious solution to our data (Marôco, 2014). Thus, considering the overall results, the two-factor solution reported in other multicultural studies presents a good fit to our data.

Regarding the item loadings, 19 of the items obtained high factor weights ($\lambda \geq 0.59$; Hair, Black, Babin, & Anderson, 2009) in this two-factor model; item 5 was the only presenting a low factor weight ($\lambda = .19$) (see item loadings in Table 2). Interestingly, this same item has obtained low factor weights in other studies that have explored the factorial structure of the data (e.g., Dorr, 1981; Hedl & Papay, 1982). Importantly, the inclusion of item 5 did not preclude our two-factor solution from producing good adjustment results. In a CFA conducted with the exclusion of item 5, the following values were obtained: $\chi^2(151) = 454.08$; $p < .001$; CFI = .94; PCFI = .83; TLI = 0.93; RMSEA = .070; P(rmsea<=0.05) < .001; AIC = 570.08; WRMR = 1.43. In this solution, all items obtained factor weights $\lambda \geq 0.59$. Given that other studies opted to maintain the original structure of the scale, the fact that our data with the full scale obtained overall good fit to the two-factor model, and to allow multicultural comparisons of the scale, we decided to maintain the full scale.

Table 1. *Psychometric indexes obtained in the CFA when considering one- and two-factor solutions. We also provide the results regarding the test of the measurement invariance by gender of the two-factor model (dataset-1)*

	χ^2	**df**	**CFI**	**PCFI**	**TLI**	**RMSEA**	**P[rmsea ≤ 0.05]**	**AIC**	**WRMR**
Overall Sample									
One-factor	958.27	170	.842	.753	.823	.107	< .001	1078.3	2.101
Two-factor#	591.77	169	.915	.814	.904	.079	< .001	713.8	1.598
Test of the measurement invariance by gender of the two-factor model									
Females	379.04	169	.932	.829	.923	.078	<.001	501.0	1.320
Males	364.91	169	.904	.804	.892	.076	<.001	486.9	1.296
Configural invariance	762.98	356	.920	.862	.915	.075	<.001	971.0	1.865
Full scalar invariance	749.00	374	.926	.911	.925	.070	<.001	921.0	1.927
Partial scalar invariance	740.71	372	.927	.907	.926	.070	<.001	916.7	1.914

Notes: #Model that produced the best indexes. CFI=Comparative Fit Index, good adjustment values between .90-.95; PCFI=Parsimony Comparative Fit Index, very good adjustment values when ≥ .80; TLI=Tucker Lewis Index, reasonable adjustment between .80-.90, good adjustment values between .90-.95; RMSEA=Root Mean Square Error of Approximation, good adjustment between .05-.10; AIC=Akaike Information Criterion, the lowest the value the better adjustment. The characterization of these values follows a systemization of the relevant information provided by Marôco (2014, p.51). WRMR=Weighted Root Mean Square Residual, < .90 (Muthén & Muthén, 2012).

Table 2. *Component loadings obtained in the Confirmatory Analyses using the Weighted Least Squares with Mean and Variance adjustment (WLSMV) estimator (Finney & diStefano, 2006) (dataset-1)*

	Component Loadings		
	One-factor model	Two-factor model	
		Factor 1	Factor 2
ITEM 1	0.603	0.622	--
ITEM 2	0.571	--	0.658
ITEM 3	0.558	0.590	--
ITEM 4	0.538	--	0.652
ITEM 5	0.093	--	0.193
ITEM 6	0.628	0.656	--
ITEM 7	0.770	--	0.926
ITEM 8	0.603	0.634	--
ITEM 9	0.666	--	0.794
ITEM 10	0.695	0.721	--
ITEM 11	0.649	--	0.759
ITEM 12	0.709	0.735	--
ITEM 13	0.789	0.824	--
ITEM 14	0.839	0.874	--
ITEM 15	0.657	--	0.789
ITEM 16	0.768	--	0.876
ITEM 17	0.770	0.792	--
ITEM 18	0.600	--	0.707
ITEM 19	0.630	--	0.735
ITEM 20	0.830	0.849	--

We have also explored whether this two-factor structure is stable for both females and males by testing the configural invariance. Additionally, we explored the scalar invariance which tests if the item loadings on each factor and thresholds are equal between groups. Results are provided in Table 1. Full scalar invariance was not obtained because the model fit was significantly damaged by the constraints imposed to the baseline model ($\Delta\chi 2 = 29.299$, $df = 18$, $p = .045$). The modification indexes suggest that the threshold of item 10 is variant between groups, while holding all loading values similar across groups. A non-significant difference between the partially constrained and the unconstrained (configural) model was obtained when we allowed the variability of this threshold ($\Delta\chi2 = 23.27$, $df = 16$, $p = .106$). Given that we obtained partial scalar invariance, the mean levels of the constructs can be compared (Hair et al., 2009). No similar test was made for the different school cycle groups given the inadequate sample size of the groups (i.e., < 200; Dimitrov, 2010).

The convergent validity of the two-factor model, as assessed by the AVE, revealed the value of 0.54 for both factors (“anxiety-absent” and “anxiety-present”), a value higher than that usually regarded as adequate (≥ 0.5; Hair et al, 2009). The discriminant validity was calculated by comparing the AVE of each factor with the square of the correlation between the two factors ($r = .639$) (Anderson & Gerbing, 1988). The later value ($r^2 = 0.41$) was lower than the AVE values obtained for each factor confirming their discriminant validity.

Reliability

The results regarding the internal consistency (Cronbach's α) and the test-retest reliability (ICC) for each factor are presented in Table 3 for the total sample and also according to sex and school cycle of the participants. Both factors obtained a good internal consistency with alpha values well above the acceptable cut-off value of 0.7 (Nunnally & Bernstein, 1994). This same conclusion was obtained when the analysis was run using dataset-2 (Cronbach's $\alpha_{Anxiety\_Absent}$=0.90, $\alpha_{Anxiety\_Present}$=0.83; Further information about other results obtained using dataset-2 can be obtained by contacting the corresponding author). The ICC values are also higher than the cut-off points defined by Fleiss, Levin, and Paik (2003) for an acceptable test-retest reliability ($0.4 \leq ICC < 0.75$). Regarding the composite reliability, which reflects the internal consistency of the items within a factor, for the two factors the values were above 0.70 indicating an appropriate composite reliability ($CR_{Anxiety\text{-}Absent} = 0.921$; $CR_{Anxiety\text{-}Present} = 0.916$).

Descriptive Values, Sex and School Cycle Groups

The overall mean score obtained was 29.43 ($SD = 5.70$). The descriptive values broken down by sex and school cycle are presented in Table 3. Although girls reported experiencing higher levels of anxiety than boys, the difference was only statistically marginal, *t*(403) = 1.85, $p = .07$, $d = 0.183$. The repeated-measures ANOVA considering the two factors (within-subject variable) and sex (between-subjects variable) confirmed no significant effect of sex nor interaction, $F(1,403) = 3.42$, $MSE = 16.15$, $p = .065$, and $F(1,403) = 1.70$, $MSE = 12.05$, $p = .19$, respectively, but a significant effect of factor, $F(1, 403) = 653.51$, $MSE = 7.10$, $p < .001$, $\eta_p^2 = .62$; The latter reflects a higher score of the anxiety-absent as compared to the anxiety-present factor (see Table 3). Regarding the school cycle groups, the participants from the first cycle reported higher anxiety those from the remaining groups. Participants from the third cycle also revealed higher anxiety than participants from the second school cycle. However, a one-way ANOVA revealed a non-significant effect of school cycle on state-anxiety, F (2, 402) = 1.25, $p = .29$. This comparison among school cycle groups should be considered only exploratory given that we did not test measurement invariance for these groups.

Table 3. *Descriptive data and reliability measures of the SASC for the total sample, as well as according to the sex and school cycle of the participants (dataset-1)*

		Sex		School Cycle		
	Total Sample (N = 405)	Boys (N=203)	Girls (N=202)	1st cycle (N = 100)	2nd cycle (N = 78)	3rd cycle (N = 227)
Descriptive Data						
Mean (SD): Total Scale	29.43 (5.70)	28.91 (5.25)	29.95 (6.09)	30.12 (6.66)	28.79 (5.51)	29.34 (5.29)
Mean (SD): Factor 1 - Anxiety absent	17.11 (3.92)	16.72 (3.90)	17.49 (3.92)	16.53 (4.24)	16.37 (3.80)	17.61 (3.76)
Mean (SD): Factor 2 - Anxiety present	12.32 (2.83)	12.18 (2.62)	12.46 (3.02)	13.59 (3.51)	12.42 (2.68)	11.73 (2.31)
Reliability Measures						
Factor 1: Anxiety absent						
Cronbach's α	.863	.859	.865	.858	.859	.867
Test-retest reliability (ICC)	.796	.784	.804	.769	.823	.791
Factor 2: Anxiety present						
Cronbach's α	.780	.751	.804	.801	.756	.762
Test-retest reliability (ICC)	.720	.680	.750	.633	.819	.715

Notes: The 1st cycle group includes participants attending the third and fourth grades; the 2nd cycle group includes participants attending the fifth and sixth grades; the 3rd cycle group includes participants attending the seventh and eighth grades.

Stressful Event and State-anxiety

The comparison between the anxiety levels reported when a stressful event was occurring with those obtained in the absence of a stressor indicates whether the instrument is sensitive to the presence/absence of specific stressors. In our sample, 93 participants reported experiencing a stressful event in only one of the administration moments; 35 of the participants reported the stressor in the first and 58 in the second administration. A paired *t*-test revealed that in the presence of the stressor, participants reported significantly higher anxiety than in its absence (M = 29.1, SD = 5.9; and M = 27.8, SD = 6.3, respectively), $t(92) = 2.07$, $p = .041$, $d = .215$. This result was also confirmed when sex was considered as a between-subjects variable in a repeated-measures ANOVA. Specifically, a significant main effect of stressor was found, $F(1,91) = 4.52$, $MSE = 17.29$, $p = .036$, $\eta_p^2 = 0.047$, but the main effect of sex and the interaction were non-significant, both $Fs<1$ (see descriptive values by sex in Table 4). These results should be seen as exploratory given the small number of participants involved.

Table 4. *Mean (and SD) values obtained for females and males when a stressor was present and absent. We also provide information on the sample size and mean age (datasets-1 and -2)*

	N	Mean Age (SD)	With stressor	Without stressor
Total	93	11.44 (1.75)	29.1 (5.9)	27.8 (6.3)
Females	51	11.41 (1.79)	29.3 (5.2)	28.4 (6.1)
Males	42	11.48 (1.73)	28.8 (6.8)	27.1 (6.6)

Discussion

This study presents an initial adaptation for European Portuguese children and adolescents of the SASC. Our data revealed good psychometric properties. No significant differences were found between sexes in our sample, a result that is consistent with previous validation studies (e.g., Day et al., 1986; Gómez-Fernández & Spielberger, 1990; Psychountaki et al., 2003), and the original work (Spielberger et al., 1973). Nonetheless, sex differences are typically observed on the more stable individual difference of the propensity to react anxiously to stressor events (trait-anxiety), with females reporting higher anxiety than males (e.g., Day, et al., 1986). Researchers have proposed possible explanations for these observed differences in trait-anxiety (e.g., males are usually less willing to admit their fears or emotions; Nakazato & Shimonaka, 1989), but less has been explored about state-anxiety given the inconsistent pattern of results reported in the literature as noted in the introduction.

The state-anxiety levels did not differ significantly among our school cycle groups. Given that these groups differ naturally in age, with participants attending the first cycle being the youngest and those attending the third cycle being the oldest, comparisons among our groups are somewhat informative about the relation between age and state anxiety. The results from previous studies have been mixed with some studies reporting a tendency for older participants to experience more state-anxiety than the youngest (Psychountaki et al., 2003), whereas others have reported no influence of this variable (e.g., Day et al., 1986). We should note that the age range in our study was wider than in most of the reviewed studies (e.g., Li & Lopez, 2004; Psychountaki et al., 2003); This allows a better developmental characterization of the state-anxiety but, at the same time, limits the discussion of this result. Also, the contribution of our analyses to this debate should be minor considering we were not able to evaluate measurement invariance. The absence of consistent differences among age groups could be related to the fact that this scale mostly captures anxiety reactions to specific stressors, and exposure to stressors differs greatly among people and across time. Although the relation between age and state-anxiety is not yet well established, authors have stressed that the childhood and adolescence periods are prone to the development of anxiety symptoms and should be fully characterized; to this end, validated instruments to assess anxiety are crucial (Beesdo et al., 2009).

Regarding the factorial structure, the CFA of the two-factor model provided a good fit for our data, corroborating validation studies from other countries (e.g., Li & Lopez, 2004; Psychountaki et al., 2003) and supporting the robustness of the instrument. We should note, however, that we did not explore alternative measurement models but rather tested if our data conformed to the model typically reported in the literature. Our data revealed good internal consistency as well as good test-retest reliability. The Cronbach's alphas obtained for the two factors were good and higher than or similar to those reported in other studies (e.g., Gómez-Fernández & Spielberger, 1990; Psychountaki et al., 2003; Spielberger et al., 1973). This applies for the total sample, as well as separately for each sub-group regarding sex and school cycle. Similarly to the original study (Spielberger et al., 1973), we verified that the Cronbach's alpha was higher for the female than for the male participants. Good reliability values were also obtained with dataset-2 which provides further evidence of its validity.

Regarding the temporal stability, we obtained test-retest reliability values that are similar to those reported in some other validation studies, although also somewhat higher than others (see Table 5). This result was not surprising for us given that, considering an informal analysis of the question regarding the presence of specific stressors in each assessment moment, the large majority of our sample (77%) reported no change in the presence/absence of particular stressors between the two assessment moments. There is also some variability across studies in the intervals between the test-retest moments which could mediate these differences.

The consideration of the influence of a specific stressor on state-anxiety provides additional preliminary evidence for the construct validity of the scale. Specifically, higher anxiety was reported when participants were dealing with a specific stressor as compared to when no stressor was present. Previous studies have provided similar results. For example, in Li and Lopez (2004), participants' state-anxiety was higher prior to being submitted to an examination period at school, as compared to after performing such examination. Both in our and in Li and Lopez study, females and males seemed to be equally affected by the presence of the stressing event. This form of validity should be further explored in other studies by "exposing" participants to controlled stressors.

This study presents an initial adaptation and validation for Portuguese children and adolescents of one of the scales most used in the world to assess state-anxiety (Seligman et al., 2004). As noted, anxiety is present in various domains of our children and adolescents' lives (Li & Lopez, 2004; McDonald, 2001) and has many potential long-term effects (see discussion of Psychountaki et al., 2003). Besides all of the potential practical applications this instrument might have, it will also be very useful for general and, particularly, for developmental research. In Portugal, we already have a validated form of the State Anxiety Scale for Adults for the ages of 15-69 (Silva & Spielberger, 2007). Providing a validated form of the corresponding instrument for the ages of 8-14, will allow researchers and practitioners to evaluate the same dimension across time using a comparable measure. Similar cases can be found in the literature: In Biaggio's (1985) study, anxiety in children and adults was measured using the two versions of Spielberger's instrument. This possibility adds validity to these kinds of studies. The psychometric properties we report for our scale are promising and indicate this is an appropriate instrument to assess state-anxiety in Portuguese children and adolescents. We should point to the limited geographical provenience of our sample and the lack of a concurrent validity test to propose that further studies should be conducted to fully establish the validity of this scale.

In conclusion, we present an initial validation of the SASC for European Portuguese children and adolescents with very positive psychometric properties and good adjustment to the two-factor model proposed in the literature. Given the overarching importance of state-anxiety and the wide variety of contexts in which it is relevant, this instrument will be extremely useful in applied settings as well as in research.

Table 5. *Summary of the mean values obtained for the SASC, Cronbach's α and test-retest reliabilities reported in our and in other studies*

		Mean State-Anxiety		Cronbach's α		Test-retest reliability
	Age-range	Boys	Girls	Boys	Girls	
OUR STUDY	8-14	28.97	29.94	.86 (factor 1) .75 (factor 2)	.87 (factor 1) .80 (factor 2)	.75 (factor 1) .73 (factor 2)
Greek[(a)]	9-12	27.99	27.98	.84 (factor 1) .85 (factor 2)	.85 (factor 1) .82 (factor 2)	.65 (factor 1) .67 (factor 2)
Original[(b)]	9-12	31.00	30.70	.82[§]	.87[§]	.31 (M) / .47 (F)
Matias[(c)]	9-15	29.18	29.97	.86	.88	.35 (M) / .68 (F)
Brazil[(d)]	4^{th}-6^{th} grade[#]	30.35-3.89	29.41-37.04	.84		.66
Spain[(e)]	3^{rd} grade[$]	35.26	36.32	.78	.87	n/a
Chinese[(f)]	7-12	25.4-6.93	25.20-36.12	.84-.85[*]		.78-.79[*]

Notes: [(a)]Psychountaki et al. (2003); [(b)]Spielberger et al. (1973); [(c)]Matias (2004); [(d)]Biaggio (1980); [(e)]Gómez-Fernández and Spielberger (1990); [(f)](Li & Lopez, 2004); [§]Refers to KR-20 index; [#]In the Brazilian Education System, 4^{th}-6^{th} grades frequently include children aged 9-12Y; [$]In the Spanish Education System, 3^{rd} grade commonly includes children aged 8-9Y; *Data obtained during the periods without the stressor; (M) Males; (F) Females.

Acknowledgments

Pedro F. S. Rodrigues, Pedro Bem-Haja, and Josefa N. S. Pandeirada were supported by the Portuguese Foundation for Science and Technology (Fellowships SFRH/BD/84279/2012 and SFRH/BD/85928/2012, and Research Grant IF/00058/2012/CP0172/CT0002), respectively. A special acknowledgment is made to the group of schools from Águeda, Águeda Sul, Aveiro, Estarreja, Gafanha da Nazaré, Murtosa, Oliveira do Bairro, Colégio Frei Gil, and Colégio D. José I, for their collaboration in this study. We also thank the collaboration of Lígia Ribeiro and Patrícia I. Marinho for their assistance in the data collection. We also thank Doctor Conceição Matias for providing and discussing her work with us during this study. We thank Professor Ana M. Costa (University of Aveiro) for her contribution during the translation process.

References

Anderson, J., & Gerbing, D. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin, 103*, 411-423. doi:10.1037/0033-2909.103.3.411

Beaton, D. E., Bombardier, C., Guillemin, F., & Ferraz, M. B. (2000). Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine, 25*, 3186-3191. doi:10.1097/00007632-200012150-00014

Beena, J. P. (2013). Dental subscale of children's fear survey schedule and dental caries prevalence. *European Journal of Dentistry, 7*, 181-185. doi:10.4103/1305-7456.110166

Beesdo, K., Knappe, S., & Pine, D. S. (2009). Anxiety and anxiety disorders in children and adolescents: Developmental issues and implications for DSM-V. *The Psychiatric Clinics of North America*, *32*, 483-524. doi:10.1016/j.psc.2009.06.002

Biaggio, A. M. B. (1980). Desenvolvimento da forma infantil em português do Inventário de Ansiedade Traço-Estado de Spielberger [Development of the

Portuguese version of the Spielberger state-trait anxiety inventory for children]. *Arquivos Brasileiros de Psicologia, 32*, 106-118.

Biaggio, A. M. B. (1985). Relationships between State-Trait Anxiety and locus of control-experimental studies with adults and children. *International Journal of Behavioral Development, 8*, 153-166.

Day, R. C., Knight-II, C. W., El-Nakad, L., & Spielberger, C. D. (1986). Development of an Arabic adaptation of the State-Trait Anxiety Inventory for Children. In C. D. Spielberger & R. Diaz-Guerrero (Eds.), *Cross-cultural Anxiety* (Vol. 3, pp. 113-123). Washington: Hemisphere Publishing Corporation.

Dimitrov, D. (2010). Testing for factorial invariance in the context of construct validation. *Measurement and Evaluation in Counseling and Development*, *43*, 121–149. doi:10.1177/0748175610373459

Dorr, D. (1981). Factor structure of the State-Trait Anxiety Inventory for Children. *Personality and Individual Differences, 2,* 113-117. doi:10.1016/0191-8869(81)90005-2

Finney, S. J., & diStefano, C. (2006). Non-normal and categorical data in structural equation modeling. In G. R. Hancock & R. O. Mueller (Eds.), *Structural equation modelling: A second course* (pp. 269-314). Greenwich: Information Age Publishing.

Fleiss, J., Levin, B., & Paik, M. (2003). Statistical methods for rates and proportions. New Jersey: John Wiley & Sons.

Fornell, C., & Larcker, D. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*, 39-50. doi:10.2307/3151312

Gómez-Fernández, D. E., & Spielberger, C. D. (1990). Assessment of anxiety in Spanish elementary school children. In C. D. Spielberger & R. Díaz-Guerrero (Eds.), *Cross-cultural anxiety* (Vol. 4, pp. 193-196). Washington: Hemisphere Publishing.

Hadwin, J. A., Brogan, J., & Stevenson, J. (2005). State anxiety and working memory in children: A test of processing efficiency theory. *Educational Psychology, 25*, 379-393. doi:10.1080/01443410500041607

Hair, J. F., Jr., Black, W. C., Babin, B. J., & Anderson, R. E. (2009). *Multivariate data analysis* (7th ed.). Upper Saddle River: Prentice Hall.

Hedl, J. J., & Papay, J. P. (1982). The factor structure of the State-Trait Anxiety Inventory for Children: Kindergarten through the fourth grades. *Personality and Individual Differences, 3*, 439-446. doi:10.1016/0191-8869(82)90008-3

Li, H. C. W., & Lopez, V. (2004). Psychometric evaluation of the Chinese version of the State Anxiety Scale for Children. *Research in Nursing & Health, 27*, 198-207. doi:10.1002/nur.20015

Lorenzo-Seva, U., & Ferrando, P. J. (2014). POLYMAT-C: A comprehensive SPSS program for computing the polychoric correlation matrix. *Behavior Research Methods, 47,* 884-889. doi:10.3758/s13428-014-0511-x

Marôco, J. (2014). *Analysis of structural equations: Theoretical basis, software & applications*. Lisboa: ReportNumber.

Matias, C. (2004). *Aferição do State-Trait Anxiety Inventory for Children (STAIC) de Spielberger para a população portuguesa [Standardization of the Spielberger's State-Trait Anxiety Inventory for Children (STAIC) for the Portuguese population]*. (PhD thesis), Universidade de Badajoz, Badajoz.

Mazzone, L., Ducci, F., Scoto, M. C., Passaniti, E., D'Arrigo, V. G., & Vitiello, B. (2007). The role of anxiety symptoms in school performance in a community sample of children and adolescents. *BMC Public Health, 7*. doi:10.1186/1471-2458-7-347

McDonald, A. S. (2001). The prevalence and effects of test anxiety in school children. *Educational Psychology, 21*, 89-101. doi:10.1080/01443410020019867

Merikangas, K. R., Nakamura, E. F., & Kessler, R. C. (2009). Epidemiology of mental disorders in children and adolescents. *Dialogues in Clinical Neuroscience, 11*, 7-20.

Muthén, L.K., & Muthén, B.O. (2012). *Mplus User's Guide (7th Ed.)*. Los Angeles, CA: Muthén & Muthén

Nakazato, K., & Shimonaka, Y. (1989). The Japanese State-Trait Anxiety Inventory: Age and sex differences. *Perceptual and Motor Skills, 69*, 611-617. doi:10.2466/pms.1989.69.2.611

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory*. New York: McGraw-Hill.

Psychountaki, M., Zervas, Y., Karteroliotis, K., & Spielberger, C. (2003). Reliability and validity of the Greek version of the STAIC. *European Journal of Psychological Assessment, 19*, 124-130. doi:10.1027//1015-5759.19.2.124

Raveis, V. H., Siegel, K., & Karus, D. (1999). Children's psychological distress following the death of a parent. *Journal of Youth and Adolescence, 28*, 165-180. doi:10.1023/A:1021697230387

Ryan, C. (2004). Gender differences in children’s experience of musical performance anxiety. *Psychology of Music, 32*, 89-103. doi:10.1177/0305735604039284

Seligman, L. D., Ollendick, T. H., Langley, A. K., & Baldacci, H. B. (2004). The utility of measures of child and adolescent anxiety: A meta-analytic review of the revised children's manifest anxiety scale, the state–trait anxiety inventory for children, and the child behavior checklist. *Journal of Clinical Child & Adolescent Psychology, 33*, 557-565. doi:10.1207/s15374424jccp3303_13

Settipani, C., & Kendall, P. (2013). Social functioning in youth with anxiety disorders: Association with anxiety severity and outcomes from cognitive-behavioral therapy. *Child Psychiatry & Human Development, 44*, 1-18. doi:10.1007/s10578-012-0307-0

Silva, D. (2003). Inventário de estado-traço de ansiedade (STAI). *Avaliação Psicológica: instrumentos validados para a população portuguesa* [Psychological assessment: Validated instruments for Portuguese population]. (Vol. 1, pp. 45-63). Coimbra: Quarteto Editora.

Simon, J. A., & Martens, R. (1979). Children's anxiety in sport and nonsport evaluative activities. *Journal of Sport Psychology, 1*, 160-169. doi:10.1123/jsp.1.2.160

Spielberger, C. D., Edwards, C. D., Lushene, R., Monturoi, J., & Platzek, D. (1973). *State-Trait Anxiety Inventory for Children: Sampler set, manual, test booklet, scoring key*. Palo Alto, CA: Mind Garden.

Spielberger, C. D., Edwards, C. D., Lushene, R., Monturoi, J., & Platzek, D. (2009). *Cuestionario de autoevaluación Ansiedade Estado / Rasgo en niños: Manual* (4th ed.). Madrid: TEA.

Wechsler, A., & Sánchez-Iglesias, I. (2013). Psychological adjustment of children with cancer as compared with healthy children: A meta-analysis. *European Journal of Cancer Care*, *22*, 314-325. doi:10.1111/ecc.12031

Wu, P., Goodwin, R. D., Fuller, C., Liu, X., Comer, J. S., Cohen, P., & Hoven, C. W. (2010). The relationship between anxiety disorders and substance use among adolescents in the community: Specificity and gender differences. *Journal of Youth and Adolescence*, *39*, 177-188. doi:10.1007/s10964-008-9385-5

Appendix 2

The Trait Anxiety Scale for Children: A validation study for European Portuguese children and adolescents

| Copy of the accepted version of the article |

(Rodrigues, Pandeirada, Bem-Haja, & França, 2017;
doi: 10.1080/17405629.2017.1308249)

This is the accepted version of the Manuscript published online by Taylor & Francis.

Final version available at:

http://www.tandfonline.com/doi/full/10.1080/17405629.2017.1308249

Reference

Rodrigues, P. F. S., Pandeirada, J. N. S., Bem-Haja, P., & França, J. (2017). The Trait Anxiety Scale for Children: A validation study for European Portuguese children and adolescents. *European Journal of Developmental Psychology*, 1-9. doi: 10.1080/17405629.2017.1308249

The Trait Anxiety Scale for Children: A validation study for European Portuguese children and adolescents

Pedro F. S. Rodrigues[a,b*], Josefa N. S. Pandeirada[a,c*], Pedro Bem-Haja[a,b*], and Joana França[d]

[a]Department of Education and Psychology, University of Aveiro, Campus Universitário de Santiago, Aveiro, Portugal; [b]IBILI, University of Coimbra, Coimbra, Portugal; [c]CINTESIS.UA, Aveiro, Portugal; [d]Câmara Municipal de Estarreja, Estarreja, Portugal.

Abstract

The State-Trait Anxiety Inventory for Children is a self-report instrument inspired on the State-Trait theory extended by Spielberger that measures a momentary state of anxiety (state) and a stable tendency to experience anxiety (trait). This study presents an exploratory adaptation of the Trait Scale and provides its psychometric properties for European Portuguese children and adolescents. The influence of sex and age were also explored. Our sample, composed of 402 participants aged 8-14 years, revealed a mean anxiety value of 28.37 (*SD* = 5.99). As expected, females revealed higher levels of anxiety than boys. Higher anxiety was obtained in our youngest group as compared to the oldest group. The exploratory factor analysis led to retaining only 16-items that presented acceptable adjustment to a one-factorial solution. Good indexes were obtained in the confirmatory analysis. The results also revealed good internal consistency and good test-retest reliability. Our results provide initial evidence that this scale is adequate to measure trait-anxiety in European Portuguese young people.

Keywords: Trait Anxiety; Trait Anxiety Scale for Children (TASC); European Portuguese children; European Portuguese adolescents; psychometric proprieties

---

[*] The first three authors have contributed equally to this work and share first authorship in the paper. *Corresponding author:* Josefa N. S. Pandeirada ✉ josefa@ua.pt

Introduction

Anxiety is an essential brain response that allows individuals to adapt to real or potential threats. However, sometimes this response is excessive and maladaptive becoming a psychopathological condition (e.g., Perkins & Corr, 2014). Particularly in children and adolescents, anxiety disorders are one of the most common psychopathologies that negatively impact various areas (e.g., Mazzone et al., 2007). Additionally, when occurring at young ages, they tend to prevail into adulthood and are also frequently related with other psychopathologies (Beesdo, Knappe, & Pine, 2009).

The State-Trait Anxiety Inventory for Children (STAIC; Spielberger, Edwards, Lushene, Monturoi, & Platzek, 1973) is widely used to assess anxiety in young people (Beesdo et al., 2009). This instrument includes two independent scales: The State Scale - aims to measure the current feelings of anxiety, and the Trait Scale - assesses a more stable and long-lasting tendency to experience anxiety. This work focused on the latter, henceforth designated by *Trait Anxiety Scale for Children* (TASC).

The TASC has been used in various research areas denoting its utility to measure children and adolescents' anxiety. For example, it has been used to characterize clinical and non-clinical samples in studies on anxiety disorders and to assess the effectiveness of intervention programs (e.g., Seligman, Ollendick, Langley, & Baldacci, 2004). In health-related settings it has been useful to assess psychological adjustment (e.g., Wechsler & Sánchez-Iglesias, 2013). Studies exploring the relation between anxiety and cognitive performance have also used this instrument (e.g., Owens, Stevenson, Hadwin, & Norgate, 2014). Finally, professionals dealing with anxiety-related problems in clinical and educational settings frequently use it (Psychountaki, Zervas, Karteroliotis, & Spielberger, 2003). Thus, the potential utility of this instrument is as large as the variety of these examples.

The TASC has been translated and adapted into several languages, such as Brazilian Portuguese[17] (Biaggio, 1980), Spanish (Gómez-Fernández & Spielberger,

[17] One could question the need to adapt this instrument into European Portuguese considering the existence of a Portuguese Brazilian version. Considering that the two countries have substantial cultural (Brazil is mostly influenced by a South-American culture, whereas Portugal, being a European country, has a western culture), as well as language differences (both grammatically and in typical expressions), the Brazilian version would not be appropriate to evaluate trait-anxiety in European Portuguese children and adolescents.

1990), Greek (Psychountaki et al., 2003), and Chinese (Li & Lopez, 2004), with most studies revealing good psychometric proprieties. Additionally, when applicable, these studies have supported the one-factor solution of the scale proposed in studies that have specifically assessed its factorial structure (Cross & Huberty, 1993; Dorr, 1981; Hedl & Papay, 1982). A couple of adaptation studies have been conducted in Portugal but they do not provide a full psychometric characterization of the scale. Specifically, Dias and Gonçalves (1999) only reported Cronbach's alfa as a measure of reliability; Neither this study nor the one by Matias (2004) presented a Confirmatory Factor Analysis (CFA). The current work aims to overcome these limitations.

Developmental research and practitioners will also benefit from this instrument as the analogous instrument to assess anxiety in 15-69 years-old individuals - the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) - has been validated in Portugal and is widely used (Silva, 2003). Providing a validated TASC for young ages will allow practitioners and researchers to use a similar instrument to assess trait-anxiety across different developmental periods. Although TASC was originally designed for ages 9-12, it can be used in younger or older children (Spielberger et al., 1973). We chose the age range of 8-14 years to cover a wider developmental period and to potentiate the utility of the instrument. Thus, a similar instrument to assess trait-anxiety in ages 8-69 will become available which will improve the reliability of developmental comparisons. We acknowledge, however, the existence of alternative instruments in Portugal to assess anxiety in children which differ in many respects (e.g., CMAS-R-Dias & Gonçalves, 1999; SCARED-R-Pereira & Barros, 2010).

In this study participants responded to the scale in two different moments allowing us to assess its test-retest reliability. The following aims were pursued: (1) translate and adapt the TASC for European Portuguese children and adolescents[18]; (2) provide its preliminary psychometric properties; (3) evaluate its factorial structure via Exploratory Factor Analysis (EFA) using the first administration data (data-set-1), and

[18] During the entire process of adaptation of the instrument, we complied with all the formal requirements imposed by Mind Garden, Inc.©, owner of the copyrights of the instrument which, when contacted, informed us of the inexistence of a validated European Portuguese version of this instrument. We also thank Mind Garden, Inc.© for their sponsorship of this project and Professor Ana M. Costa (University of Aveiro) for her contribution to this translation process.

then confirm it using CFA with the second administration data (data-set-2); and, (4) assess anxiety differences between sexes and among age groups.

Method

Participants and procedure

Participants aged 8-14 years were recruited from seven schools of the Aveiro district (Portugal)[19]. Schools were selected by convenience while providing participants from different educational environments. Previous consent for participating was obtained from the participant's guardians and from the participants (for more details see Supplementary Material [SM]-1). The characterization of the sample is presented in Table 1. The scale was administered in groups of 12-28 participants by one of the authors in two independent sessions lasting approximately 15-20 minutes (interval between test-retest was 3-4 weeks).

20

Measures

The *TASC* includes 20-items that describe anxiety experiences a person might experience (e.g., item 6-"I worry too much"©). For each item, participants choose one of three options that indicate how often they experience the described situation - "hardly-ever", "sometimes" or "often"; these options are scored with 1, 2, and 3 points, respectively (total score range: 20-60). Higher scores indicate higher anxiety.

The translation of the TASC included four phases: (1) translation of the original questionnaire to European Portuguese by two of the authors highly proficient in English; (2) blind back-translation by an English Professor from the University of Aveiro; (3) examination of the translated and retranslated versions and adjustment of some of the terms by two of the authors highly proficient in English; and, (4) implementation of a think-aloud protocol by two psychologists with clinical experience

[19] A special acknowledgment is made to the group of schools from Águeda, Águeda-Sul, Aveiro, Estarreja, Murtosa, Oliveira do Bairro, Colégio Frei Gil, and Colégio D. José I, for their collaboration in this study. We also thank the collaboration of Lígia Ribeiro and Patrícia I. Marinho for their assistance in the data collection.

with 15 children and adolescents (M_{age} = 9.87; *SD* = 2.26) to assess understandability of the items.

Results

Overall results, sex and age groups comparisons

A description of the conducted analysis is presented in SM-2 and the raw database corresponds to SM-6.

Our sample revealed an anxiety mean score of 28.37 (*SD* = 5.99) for the 16-items scale (see analysis below), with scores non-normally distributed (Skewness = .386; Kurtosis = -.054). The overall descriptive data broken down by sex and age groups and the corresponding normality tests, are presented respectively, in Table 1 and in SM-3. An independent samples *t*-test revealed significantly higher anxiety values in females than in males, $t(394.3) = 3.89$, $p < .001$, $d = 0.39$. Additionally, the Oneway ANOVA revealed a reliable main effect of age group, $F(2,399) = 6.10$, $p = .002$, $\mu_p^2 = .03$; The pairwise comparisons between groups revealed that the younger group reported significantly higher levels of anxiety than the older one ($p = .002$); no other significant differences were obtained for the remaining comparisons (lowest $p = .348$).

Table 1. Sample and sub-samples sizes and percentages from the total sample. The Means and Standard Deviations regarding age, as well as the total trait-anxiety score obtained from the 16-items scale, are also presented for the total sample and according to sex and age groups.

	Groups		Age		TASC Totals	
	N	*%*	*Mean*	*SD*	*Mean*	*SD*
Total Sample	402	100	11.40	1.87	28.37	5.99
Sex						
Girls	202	50.25	11.50	1.86	29.51	6.25
Boys	200	49.75	11.29	1.87	27.23	5.49
Age groups						
Youngest	101	25.12	8.88	.70	30.02	5.44
Intermediate	75	18.66	10.43	.62	28.60	6.09
Oldest	226	56.22	12.84	.78	27.56	6.05

Note: See more details regarding the definition of the age groups in Supplementary Material 1.

Factorial Structure [21]

First we conducted an EFA using data-set-1 and then, a CFA using data-set-2. Given the categorical nature of the scale, and the violation of multivariate normality in both datasets (Mardia's Test; g1p = 33.897, g2p = 456.943; chi.skew = 22271.13, $p < .001$; z.kurtosis = 5.726, $p < .001$, for data-set-1; Mardia's Test; g1p = 36.155, g2p = 471.931; chi.skew = 2422.396, $p < .001$; z.kurtosis = 10.791, $p < .001$, for data-set-2), the Weighted Least Squares with Mean and Variance adjustment (WLSMV; Finney & DiStefano, 2006) estimator, which relies on the polychoric correlation matrix[4], was used in both analyses. Analyses were conducted using M-Plus 7.4 (Muthén & Muthén, 2012). The screeplot analysis indicated retaining a maximum of two factors. Both the 1- and 2-factors solutions achieved acceptable global adjustment. Given that the confidence interval for the RMSEA overlapped between these solutions, because a 1-factor solution has been put forward in the literature, and looking for the most parsimonious model (Fabrigar, Wegener, MacCallum, & Strahan, 1999), we opted for the 1-factor solution $X^2(170) = 395.348$; $p < .001$; $X^2/df = 2.326$; CFI = .908; PCFI = .81; RMSEA = .057; $P(\text{rmsea} \leq 0.05) < .049$) (see also SM-4). Considering a minimum loading of .40, items 8, 11, 15 and 16 fell below the criteria for practical significance (Hair, Black, Babin, & Anderson, 2014). Their exclusion led to an acceptable 1-factor solution via an EFA.

To confirm the 16-items one-factor solution obtained by the exploratory method, we conducted a CFA using data-set-2. This model revealed an acceptable global adjustment, $X^2(104) = 340.431$; $p < .001$; $X^2/df = 3.273$; CFI = .927; PCFI = .803; RMSEA = .075; $P(\text{rmsea} \leq 0.05) < .001$. All the items reached high factor weights ($\lambda \geq .5$) and appropriate individual reliabilities ($R^2 \geq .25$), showing good local adjustment and indicating to be a reflection of the latent factor being measured (Marôco, 2014) (see also SM-4). Importantly, by eliminating these 4-items we only lose 4.2% (adjusted-$R^2 = .958$) and 3.5% (adjusted-$R^2 = .965$) of the explained variance of the final score with 20-items from data-set-1 and data-set-2, respectively.

[4] We would like to thank one of the reviewers for calling our attention to this issue.

Reliability

To evaluate the reliability of the 16-items scale, we assessed the internal consistency (Cronbach's α), the test-retest reliability (Intraclass Correlation Coefficient-ICC) and the composite reliability (construct reliability using the method of Fornell & Larcker, 1981) (see Table 2). We obtained a good internal consistency considering our overall α > .80 (Nunnally & Bernstein, 1994). The overall ICC value was above .75, the cut-off point defined by Fleiss, Levin, and Paik (2003) for a good test-retest reliability. The composite reliability value above .70 (CR_{TASC} = .915) indicates an appropriate construct reliability.

Table 2: Internal consistency and reliability data of the 16-items model of TASC for the total sample, by sex and by age groups.

	Total Sample	Sex		Age Group		
		Boys	Girls	Youngest	Intermediate	Oldest
Cronbach's α	.873	.864	.875	.853	.885	.879
Mean inter-item correlation	.301	.286	.304	.264	.332	.313
Mean corrected item-total correlation	.510	.495	.514	.474	.541	.523
Test-retest reliability (ICC)	.757	.706	.785	.712	.832	.757

Discussion

This study presents preliminary evidence for a reliable and valid scale to assess trait-anxiety in European Portuguese children and adolescents. We performed a proper translation process and a CFA, elements lacking in the previous Portuguese validation studies. Our participants reported overall anxiety levels similar to those obtained in other countries (e.g., Greece) as well as in the most recent Portuguese study by Matias (2004) (see a brief summary in SM-5).

Our result of higher anxiety in females than males is consistent with previous validation studies (e.g., Matias, 2004; Psychountaki et al., 2003) and with studies that specifically explored sex differences in anxiety (e.g., Chaplin & Aldao, 2013). This result confirms that our instrument is sensitive to sex differences which contributes to establish its validity. The influence of age on anxiety is less consensual in the literature. In our study, only the youngest group reported significantly higher anxiety than the oldest which diverges from studies where no differences were found (e.g., Matias, 2004). However, the anxiety reported by the Youngest and Intermediate age groups did not differ significantly which is consistent with other work (e.g., Psychountaki et al., 2003). Older participants tend to exhibit higher anxiety than younger children (Kozina, 2014), but few studies have compared age groups similar to ours which limits our discussion of this variable.

The exploratory analysis revealed that 4-items did not organize into coherent factors. The remaining 16-items saturated in a consistent way to a single factor. The one-factor solution of the 16-items was confirmed with good global and local adjustments. Previous studies that specifically tested the factorial structure of this scale (e.g., Cross & Huberty, 1993; Dorr, 1981; Hedl & Papay, 1982), and other validation studies (e.g., Chinese-Li & Lopez, 2004; Greek-Psychountaki et al., 2003) have also argued for a one-factor structure. Although they maintained the 20-items instrument, their factorial analyses indicated that some items did not adequately saturate the one-factor solution. Interestingly, three of the 4-items we excluded, namely items 8, 15 and 16, have consistently failed to reach a reasonable saturation level in several of these studies (e.g., Cross & Huberty, 1993; Dorr, 1981; Matias, 2004; Psychountaki et al., 2003). The other item differs, though, which could be related to cultural differences, one of the reasons underlying the need to adapt instruments for the population of interest (Beaton, Bombardier, Guillemin, & Ferraz, 2000).

This 16-items scale revealed good internal and test-retest consistency. These values are generally better than those obtained in the abovementioned studies without losing a significant amount of the explained variance (see SM-5 for a summary of similar reliability indexes reported in other studies).

We propose an adaptation of TASC for European Portuguese children and adolescents. These results should be taken as an initial adaptation given a few limitations of the study such as the circumscribed geographical provenience of our sample and the lack of a concurrent validity test. Future studies including samples from other regions of Portugal and exploring the concurrent validity of this scale, would contribute to establish its validity. The universal usage of this instrument speaks for its overarching impact in the study and consideration of this individual characteristic that plays a major role in a wide variety of contexts. Providing validated instruments for other researchers and professionals wishing to assess anxiety is quintessential to assure the adequate study of this characteristic.

Acknowledgments

We also thank Dr. Paula Vagos for her valuable comments and collaboration in this work.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

Pedro F. S. Rodrigues, Pedro Bem-Haja and Josefa N. S. Pandeirada were supported by the Portuguese Foundation for Science and Technology Fellowships [SFRH/BD/84279/2012], [SFRH/BD/85928/2012], and Research Grant [IF/00058/2012], respectively.

References

Beaton, D. E., Bombardier, C., Guillemin, F., & Ferraz, M. B. (2000). Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine*, *25*, 3186-3191. doi:10.1097/00007632-200012150-00014

Beesdo, K., Knappe, S., & Pine, D. S. (2009). Anxiety and anxiety disorders in children and adolescents: Developmental issues and implications for DSM-V. *The Psychiatric Clinics of North America*, *32*, 483-524. doi:10.1016/j.psc.2009.06.002

Biaggio, A. M. B. (1980). Desenvolvimento da forma infantil em português do inventário de ansiedade traço-estado de Spielberger [Development of the Portuguese version of the Spielberger state-trait anxiety inventory for children]. *Arquivos Brasileiros de Psicologia*, *32*, 106-118.

Chaplin, T. M., & Aldao, A. (2013). Gender differences in emotion expression in children: A meta-analytic review. *Psychological Bulletin, 139*, 735-765. doi:10.1037/a0030737

Cross, R. W., & Huberty, T. J. (1993). Factor analysis of the State-Trait Anxiety Inventory for Children with a sample of seventh-and eighth-grade students. *Journal of Psychoeducational Assessment, 11*, 232-241. doi:10.1177/073428299301100303

Dias, P., & Gonçalves, M. (1999). Avaliação da ansiedade e da depressão em crianças e adolescentes (STAIC-C2, CMAS-R, FSSC-R e CDI): Estudo normativo para a população portuguesa [Evaluation of anxiety and depression in children and adolescents (STAIC-C2, CMAS-R, FSSC-R, and CDI): Normative study for Portuguese population]. In A.P. Soares, S. Araújo & S. Caires (Eds.), *Avaliação Psicológica: Formas e Contextos* (Vol.VI, pp. 553-564). Braga: Apport.

Dorr, D. (1981). Factor structure of the State-Trait Anxiety Inventory for Children. *Personality and Individual Differences, 2*, 113-117. doi:10.1016/0191-8869(81)90005-2

Fabrigar, L. R., Wegener, D. T., MacCallum, R. C., & Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods, 4*, 272–299. doi:10.1037//1082-989X.4.3.272

Finney, S. J., & DiStefano, C. (2006). Non-normal and categorical data in structural equation modeling. In G.R. Hancock & R.O. Mueller (Eds.), *Structural equation modelling: A second course* (pp. 269-314). Greenwich: Information Age Publishing.

Fleiss, J., Levin, B., & Paik, M. (2003). *Statistical methods for rates and proportions.* Hoboken, NJ: Wiley.

Fornell, C., & Larcker, D. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*, 39-50. doi:10.2307/3151312

Gómez-Fernández, D. E., & Spielberger, C. D. (1990). Assessment of anxiety in Spanish elementary school children. In C.D. Spielberger & R. Díaz-Guerrero

(Eds.), *Cross-cultural anxiety* (Vol.4, pp. 193-203). Washington: Hemisphere Publishing.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2014). *Multivariate Data Analysis (7thEd.)*. USA: Pearson.

Hedl, J. J., & Papay, J. P. (1982). The factor structure of the State-Trait Anxiety Inventory for Children: Kindergarten through the fourth grades. *Personality and Individual Differences, 3*, 439-446. doi:10.1016/0191-8869(82)90008-3

Kozina, A. (2014). Developmental and time-related trends of anxiety from childhood to early adolescence: Two-wave cohort study. *European Journal of Developmental Psychology*, *11*, 546-559. doi:10.1080/17405629.2014.881284

Li, H. C. W., & Lopez, V. (2004). The reliability and validity of the Chinese version of the Trait Anxiety Scale for Children. *Research in Nursing & Health, 27*, 426-434. doi:10.1002/nur.20045

Marôco, J. (2014). *Análise de equações estruturais: Fundamentos teóricos, software & aplicações* [Analysis of structural equations: Theoretical basis, software & applications]. Lisboa: ReportNumber.

Matias, C. (2004). *Aferição do State-Trait Anxiety Inventory for Children (STAIC) de Spielberger para a população portuguesa* [Standardization of the Spielberger's State-Trait Anxiety Inventory for Children (STAIC) for the Portuguese population] (PhD thesis). Badajoz: Universidade de Badajoz.

Mazzone, L., Ducci, F., Scoto, M. C., Passaniti, E., D'Arrigo, V. G., & Vitiello, B. (2007). The role of anxiety symptoms in school performance in a community sample of children and adolescents. *BMC Public Health, 7*, 347-352. doi:10.1186/1471-2458-7-347

Muthén, L.K., & Muthén, B.O. (2012). *Mplus User's Guide (7thEd.).* Los Angeles, CA: Muthén & Muthén.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory*. New York, NY: McGraw-Hill.

Owens, M., Stevenson, J., Hadwin, J. A., & Norgate, R. (2014). When does anxiety help or hinder cognitive test performance? The role of working memory capacity. *British Journal of Psychology, 105*, 92-101. doi:10.1111/bjop.12009

Pereira, A. I., & Barros, L. (2010). *Portuguese version of the revised version of the Screen for Child Anxiety Related Emotional Disorders (SCARED-R)*. Faculty of Psychology, University of Lisbon, Portugal. Unpublished manuscript.

Perkins, A. M., & Corr, P. J. (2014). Anxiety as an adaptative emotion. In W. G. Parrott (Ed.), *The positive side of negative emotions*. New York, NY: The Guilford Press.

Psychountaki, M., Zervas, Y., Karteroliotis, K., & Spielberger, C. (2003). Reliability and validity of the Greek version of the STAIC. *European Journal of Psychological Assessment, 19*, 124-130. doi:10.1027//1015-5759.19.2.124

Seligman, L. D., Ollendick, T. H., Langley, A. K., & Baldacci, H. B. (2004). The utility of measures of child and adolescent anxiety: A meta-analytic review of the revised children's manifest anxiety scale, the state–trait anxiety inventory for children, and the child behavior checklist. *Journal of Clinical Child & Adolescent Psychology, 33*, 557-565. doi:10.1207/s15374424jccp3303_13

Silva, D. (2003). Inventário de estado-traço de ansiedade (STAI) [State-Trait Anxiety

Inventory (STAI)]. In M. M. Gonçalves, M. R. Simões, L. S. Almeida, & C. Machado (Eds.), *Avaliação Psicológica: instrumentos validados para a população portuguesa* (Vol.1, pp. 45-63). Coimbra: Quarteto Editora.

Spielberger, C. D., Edwards, C. D., Lushene, R., Monturoi, J., & Platzek, D. (1973). *State-Trait Anxiety Inventory for Children: Sampler set, manual, test booklet, scoring key*. Palo Alto, CA: Mind Garden.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Wechsler, A., & Sánchez-Iglesias, I. (2013). Psychological adjustment of children with cancer as compared with healthy children: A meta-analysis. *European Journal of Cancer Care, 22*, 314-325. doi:10.1111/ecc.12031

Supplementary Material 1

Detailed characterization of the Participants

Our sample included 402 children and adolescents aged 8-14 years recruited from schools of the Aveiro district (Portugal). Data from 13 other participants were excluded due to missing values or because they turned 15 years old between the first and second testing moments that allowed to measure the test-retest reliability of the scale.

Our age groups were created according to the school years participants were attending to which also correspond to different school levels. In Portugal, the first four years of formal education correspond to the 1st cycle of studies and includes, usually, children aged 6-10 years; our *youngest* age group belongs to this cycle and includes 101 children attending the school years 3 and 4 (M_{age} = 8.88; *SD* = 0.70). The 2nd cycle of studies corresponds to the school years 5 and 6 of formal education and normally includes children aged 10-12 years; this is our *intermediate* age group which includes 75 children (M_{age} = 10.43; *SD* = 0.62). The 3rd cycle of studies corresponds to the 7th through the 9th years of formal education being attended by adolescents aged 12-14 years; this is our *oldest* age group which includes 226 adolescents (M_{age} = 12.84; *SD* = 0.78). This form of creating the different age groups has been used in previous studies (e.g., Psychountaki et al., 2003).

Schools were selected by geographical convenience. However, in an effort to increase the representativeness of our sample regarding different educational environments we included five public and two private schools belonging from rural as well as from urban areas. Approval to conduct the study was initially obtained by the Portuguese Directorate-General for Education and the Directors of the selected schools. The to-be-tested groups were indicated by the Director of each school according to a random selection performed by each school. Parents of the children and adolescents of those groups were contacted with a request to consent the participation of the students. Previously to the collection of the data consent to participate was also obtained orally from the participants. Anonymity of the data was fully assured to participants and their parents.

Each participant responded to the scale in two different occasions. The interval between test and retest was 3-4 weeks, respecting the minimum of two weeks (e.g., Psychountaki et al., 2003). A specific code was created for each participant during the first session which allowed us to pair the responses obtained in the two assessment moments ensuring total anonymity.

In the session, each participant responded to a small set of self-report instruments. According the aim of this paper, we only report the data from the Trait Anxiety Scale for Children (TASC).

Reference

Psychountaki, M., Zervas, Y., Karteroliotis, K., & Spielberger, C. (2003). Reliability and validity of the Greek version of the STAIC. *European Journal of Psychological Assessment, 19*, 124-130. doi:10.1027//1015-5759.19.2.124

Supplementary Material 2

Data Analysis

Data Analysis was carried out with SPSS (v.22). To evaluate sex and age group differences in the total TASC scores we conducted an independent-samples *t*-test and a one-way Analysis of Variance, respectively. A Bonferroni correction was applied to the pairwise comparisons among age groups. All of these analyses were two-sided. Corrected degrees of freedom are presented when equality of variances was not obtained.

The Exploratory Factor Analysis (EFA) using the dataset-1 was conducted using the Weighted Least Squares with Mean and Variance adjustment (WLSMV; Finney & diStefano, 2006) given the categorical nature of the scale, and the fact that this dataset was not multivariate normal. This estimator relied on the polychoric correlation matrix. Global adjustment and loading values were considered when analyzing the EFA results. As a result, a new EFA was carried out using the same database but considering only the 16-items that obtained loadings of practical significance (i.e., ≥ 0.40; Hair, Black, Babin, & Anderson, 2014). A confirmatory factor analysis was then conducted using the dataset-2. Provided that this dataset was also not multivariate normal, the WLSMV estimator was again used. These analyses were conducted using M-Plus 7.4 (Muthén & Muthén, 2012).

The overall goodness-of-fit of the factor model was assessed using the following indices: χ^2/df, CFI, PCFI, RMSEA, the P[rmsea ≤ 0.05], and the Confidence Intervals of the RMSEA (e.g., Marôco, 2014). The local adjustment was evaluated by the factor weights and individual reliability of the items. A Composite Reliability, an accurate measure of factorial reliability, was calculated as described by Fornell and Larcker (1981). The internal consistency was evaluated by Cronbach's α (inter-item and item-total correlations are provided) and the test-retest reliability (temporal constancy) by the Intraclass Correlation Coefficient (ICC) (e.g., Bédard, Martin, Krueger, Brazil, 2000; Weir, 2005). The latter constitute the assessment of the reliability of the scale.

References

Bédard, M., Martin, N.J., Krueger, P., Brazil, K. (2000). Assessing reproducibility of data obtained with instruments based on continuous measurements. *Experimental Aging Research*, 26, 353-365. doi:10.1080/036107300750015741

Finney, S. J., & diStefano, C. (2006). Non-normal and categorical data in structural equation modeling. In g. R. Hancock & R. O. Mueller (Eds.), *Structural equation modelling: A second course* (pp. 269-314). Greenwich: Information Age Publishing.

Fornell, C., & Larcker, D. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*, 39-50. doi:10.2307/3151312

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2014). *Multivariate Data Analysis (7th Ed.)*. USA: Pearson.

Marôco, J. (2014). *Análise de equações estruturais: Fundamentos teóricos, software & aplicações [Analysis of structural equations: Theoretical basis, software & applications]*. Lisboa: ReportNumber.

Muthén, L.K., & Muthén, B.O. (2012). *Mplus User's Guide (7th Ed.)*. Los Angeles, CA: Muthén & Muthén.

Weir, J. P. (2005). Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *Journal of Strength and Conditioning Research*, *19*, 231-240. doi:10.1519/15184.1

Supplementary Material 3

Normality tests for the Total score (based on the final 16-items solution), results by Sex and by Age groups for datasets-1 and -2

	Mean	Score range	Skewness	Kurtosis	Kolmogorov-Smirnov[§]		
					Statistic	Df	*p*
Total score dataset-1	28.37	16-47	.386	-.054	.068	402	<.001
Total score dataset-2	27.98	16-47	.429	-.112	.064	402	<.001
Sex							
Dataset-1							
Males	27.23	16-44	.352	.004	.078	200	<.01
Females	29.51	16-47	.317	-.206	.082	202	<.01
Dataset-1							
Males	26.79	16-47	.714	.472	0.83	200	<.01
Females	28.27	16-46	.184	-.268	0.53	202	.200
Age Group							
Dataset-1							
Youngest	30.02	16-47	.488	.996	.089	101	<.01
Intermediate	28.60	17-44	.527	-.209	.102	75	.050
Oldest	27.56	16-45	.404	-.253	.081	226	<.01
Dataset-2							
Youngest	27.32	16-46	.282	.057	.076	101	.162
Intermediate	27.61	17-47	.714	.561	.083	75	.200
Oldest	27.84	16-45	.402	-.349	.074	226	<.01

Notes: [§] Lilliefors significance correction.

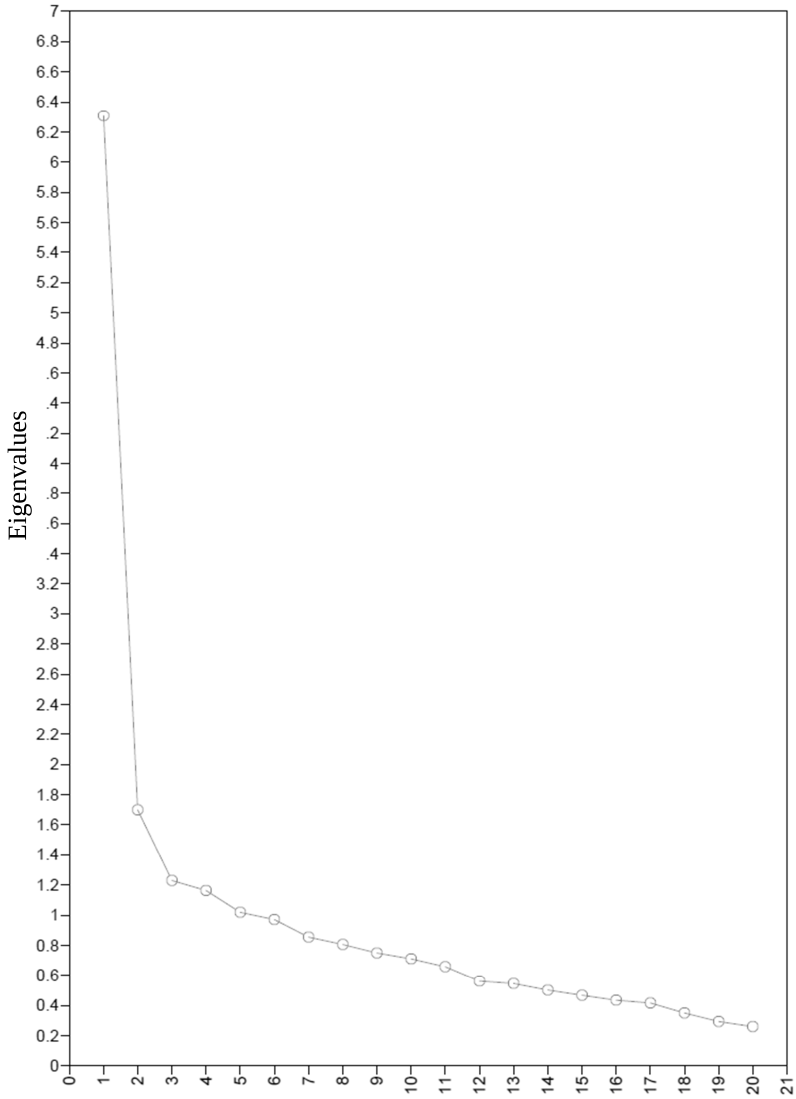
Supplementary Material 4

Comparison between the two models obtained in the Exploratory Factor Analysis using 20-items, and the Exploratory and Confirmatory Factor Analysis using the 16-items

	EFA – 20 items[a]		EFA – 16 items[a]	CFA – 16 items[b]
	1-factor model	**2-factors model**		
X^2	395.348 (df = 170)	284.396 (df = 151)	274.164 (df = 104)	340.431 (df = 104)
x^2/df	2.326	1.883	2.636	3.273
CFI	0.908	0.945	0.923	0.927
PCFI	0.812	0.751	0.799	0.803
RMSEA	0.057	0.047	0.064	0.075
CI for RMSEA	0.050-0.065	0.038-0.055	0.055-0.073	0.066-0.084

Notes: [a]analysis using dataset-1; [b]analysis using dataset-2; CI = Confidence Interval for RMSEA; X^2- the lowest the value the better the adjustment; CFI = Comparative Fit Index, good adjustment values between .9 and .95; PCFI = Parsimony Comparative Fit Index, very good adjustment values when ≥ 0.8; RMSEA = Root Mean Square Error of Approximation, good adjustment between .05 and .10. The characterization of these values follows a systemization of the relevant information provided by Marôco (2014, p.51).

Scree plot on the EFA using 20-items



Note: Only the results from the 2-factor exploratory analysis are provided given the inflection in the screeplot.

Component loadings obtained in the Exploratory and Confirmatory Analyses using the Weighted Least Squares with Mean and Variance adjustment (WLSMV) estimator (Finney, & DiStefano, 2006).

	Component Loadings		
	EFA - 20 items[a]	EFA - 16 items[a]	CFA -16 items[bc]
ITEM 1	0.520	0.512	0.569
ITEM 2	0.571	0.581	0.604
ITEM 3	0.645	0.649	0.708
ITEM 4	0.618	0.621	0.633
ITEM 5	0.611	0.619	0.696
ITEM 6	0.595	0.579	0.690
ITEM 7	0.554	0.556	0.585
ITEM 8	0.376	--	--
ITEM 9	0.541	0.562	0.603
ITEM 10	0.418	0.416	0.566
ITEM 11	0.306	--	--
ITEM 12	0.688	0.687	0.610
ITEM 13	0.599	0.600	0.572
ITEM 14	0.565	0.565	0.669
ITEM 15	0.381	--	--
ITEM 16	0.287	--	--
ITEM 17	0.662	0.645	0.715
ITEM 18	0.431	0.443	0.601
ITEM 19	0.504	0.508	0.668
ITEM 20	0.609	0.607	0.633

Notes: [a]analysis using dataset-1; [b]analysis using dataset-2; [c]Completely Standardized Component Loadings. A solid factor is present when five or more items load strongly (i.e., ≥ 0.40; Hair, Black & Babin, 2010).

SYNTAX from MPLUs for the EFA and CFA

MPlus Syntax for EFA - 20 items

```
DATA: FILE IS TASC_dataset1.dat;
VARIABLE: NAMES ARE U1-U20;
categorical are u1-u20;
ANALYSIS: TYPE = EFA 1 5;
ROTATION IS CF-VARIMAX;
PLOT: TYPE = PLOT2;
```

MPlus Syntax for EFA – 16 items

```
DATA: FILE IS TASC_dataset1.dat;
VARIABLE: NAMES ARE U1-U20;
categorical are u1-u20;
usevariables are u1-u7 u9-u10 u12-u14 u17-u20;
ANALYSIS: TYPE = EFA 1 5;
ROTATION IS CF-VARIMAX;
PLOT: TYPE = PLOT2;
```

MPlus Syntax for CFA – 16 items

```
DATA: FILE IS TASC_dataset2.dat;
VARIABLE: NAMES ARE U1-U20;
usevariables u1-u7 u9 u10 u12-u14 u17-u20;
categorical are u1-u20;
analysis: estimator is WLSMV;
MODEL: total by u1-u7 u9 u10 u12-u14 u17-u20;
OUTPUT: STANDARDIZED MODINDICES;
```

References

Finney, S. J., & DiStefano, C. (2006). Non-normal and categorical data in structural equation modeling. In g. R. Hancock & R. O. Mueller (Eds.), *Structural equation modelling: A second course* (pp. 269-314). Greenwich: Information Age Publishing.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2014). *Multivariate Data Analysis (7th Ed.)*. USA: Pearson.

Marôco, J. (2014). *Análise de equações estruturais: Fundamentos teóricos, software & aplicações [Analysis of structural equations: Theoretical basis, software & applications]*. Lisboa: ReportNumber.

Supplementary Material 5

Brief Summary of the Mean values obtained for the Trait Scale, Cronbach's α and Test-retest reliabilities reported in other validation studies

This table summarizes information about some studies for which we were able to collect the relevant information. For each study we provide the age range of the sample along with the mean values obtained in the Trait Anxiety Scale for the Male and Female participants. The age range is important to consider given that some studies have reported differences between age groups. Therefore, this piece of information should be taken into account when drawing comparisons across studies.

Regarding the comparison of the mean values, considering that our values result from a 16-items scale (total results range between 16-48), whereas in the remaining cases the total was obtained from a 20-items scale (total results range between 20-60), we applied a linear transformation to our means to make them more comparable; Again, this transformation was applied only for the sake of comparison to other studies and the conclusions should take it into account.

We also present the alfa of Cronbach which most studies present separately for Males and Females. When available, we also report the test-reliability indicators from other studies although in many cases it is not clear which statistical test was used to determine the test-retest reliability; So care should be adopted when comparing these results.

In some of the validation studies, during the adaptation process, authors added new items to the scale that differ from the original Trait scale (e.g., Brazilian and Spanish validation studies). This factor might account for some variability in the presented data.

			Mean Trait Anxiety		Cronbach's α		Test-retest reliability
		Age-range	**Males**	**Females**	**Males**	**Females**	
Portugal	**OUR STUDY**	8-14	34.04	36.89	.86	.88	.86
	Dias & Gonçalves[1]	8-17	41.70	45.61	.66	.76	
	Matias[2]	9-15	34.53	36.64	.76	.81	.78 (M) / .76 (F)
	Original[3]	9-12	36.7	38	.78	.81	.65 (M) / .71 (F)
	Brazil[4]	4th-6th grade[#]	39.39-44.86	34.70-40.44	.56		.73
	Spain*[5]	3rd grade[$]	44.41	44.00	.75	.85	n/a
	Greek[6]	9-12	34.4	36.02	.81	.78	.81
	Chinese[7]	7-12	32.88	32.81	.91	.92	.91

Notes: *The authors denote this is a particularly high score in comparison to other studies and discuss this issue extensively in their work (see page 201). [#] In the Brazilian Education System, these grades usually include children aged 9-12 years. [$] In the Spanish Education System, this grade typically includes children aged 8-9 years. M – Males; F – Females.

Study references

1. Dias, P., & Gonçalves, M. (1999). Avaliação da ansiedade e da depressão em crianças e adolescentes (STAIC-C2, CMAS-R, FSSC-R e CDI): Estudo normativo para a população portuguesa [Evaluation of anxiety and depression in children and adolescents (STAIC-C2, CMAS-R, FSSC-R, and CDI): Normative study for Portuguese population]. In AP Soares, S Araújo, & S Caires (Eds.), *Avaliação Psicológica: Formas e Contextos* (Vol. VI, pp. 553-564). Braga: Apport.

2. Matias, C. (2004). *Aferição do State-Trait Anxiety Inventory for Children (STAIC) de Spielberger para a população portuguesa* [Standardization of the Spielberger's State-Trait Anxiety Inventory for Children (STAIC) for the Portuguese population] (PhD thesis). Badajoz: Universidade de Badajoz.

3. Spielberger, C. D., Edwards, C. D., Lushene, R., Monturoi, J., & Platzek, D. (1973). *State-Trait Anxiety Inventory for Children: Sampler set, manual, test booklet, scoring key*. Palo Alto, CA: Mind Garden.

4. Biaggio, A.M.B. (1980). Desenvolvimento da forma infantil em português do inventário de ansiedade traço-estado de Spielberger [Development of the Portuguese version of the Spielberger state-trait anxiety inventory for children]. *Arquivos Brasileiros de Psicologia, 32*, 106-118.

5. Gómez-Fernández, D.E., & Spielberger, C.D. (1990). Assessment of anxiety in Spanish elementary school children. In C.D. Spielberger & R. Díaz-Guerrero (Eds.), *Cross-cultural anxiety* (Vol. 4, pp. 193-196). Washington: Hemisphere Publishing.

6. Psychountaki, M., Zervas, Y., Karteroliotis, K., & Spielberger, C. (2003). Reliability and validity of the Greek version of the STAIC. *European Journal of Psychological Assessment*, *19*, 124-130. doi:10.1027//1015-5759.19.2.124

7. Li, H. C. W., & Lopez, V. (2004). The reliability and validity of the Chinese version of the Trait Anxiety Scale for Children. *Research in Nursing & Health, 27*, 426-434. doi: 10.1002/nur.20045

Appendix 3

Morningness-eveningness preferences in Portuguese adolescents: Adaptation and psychometric validity of the H&O questionnaire

| Copy of the accepted version of the published Manuscript |

(Rodrigues et al., 2016)

This is the accepted version of the Manuscript published online by *Elsevier* in
Personality and Individual Differences, on 10-September-2015.

Reference:

Rodrigues, P. F. S., Pandeirada, J. N. S., Marinho, P. I., Bem-Haja, P., Silva, C. F., Ribeiro, L., & Fernandes, N. L. (2016). Morningness–eveningness preferences in Portuguese adolescents: Adaptation and psychometric validity of the H&O questionnaire. *Personality and Individual Differences, 88*, 62-65. doi: 10.1016/j.paid.2015.08.048

Morningness-eveningness preferences in Portuguese adolescents: Adaptation and psychometric validity of the H&O questionnaire

Pedro F. S. Rodrigues[1,2*], Josefa N. S. Pandeirada[1,2*], Patrícia I. Marinho[1,2], Pedro Bem- Haja[1,2], Carlos F. Silva[1,2], Lígia Ribeiro[3], & Natália Lisandra Fernandes[1,2]

[1]CINTESIS, Department of Education, University of Aveiro, [2]IBILI, University of Coimbra, [3]Municipality of Águeda

Abstract

Throughout development individuals vary in their circadian preferences. One of the most notable changes occurs during adolescence when individuals tend to become progressively more evening-oriented. This is a critical age period to be studied given that eveningness preferences seem to relate with physical, psychological and social problems, whereas the most morning-oriented individuals tend to be protected against these problems. The aim of this study was to adapt and present the psychometric validity of the Morningness-Eveningness Questionnaire (Horne & Ostberg, 1976) to Portuguese adolescents (12-14 years). To this end, 300 adolescents responded to the questionnaire which was initially translated, re-translated, and then subject to a think-aloud procedure. Overall, the psychometric measures were positive. We found no significant effect of sex on the circadian preferences and a tendency for increased eveningness as age progresses, especially in males. We discuss our results in light of the existing literature.

Keywords: Chronotype; Adolescents; Morningness-eveningness; Age; Gender; Psychometric validity.

Highlights: The Morningness–Eveningness Questionnaire was validated to Portuguese adolescents; We obtained good psychometric proprieties for the questionnaire; Cut-off points for the different chronotypes were presented; The majority of the Portuguese adolescents are of the intermediate type; The data were also analyzed by sex and age of the participants.

*Pedro F. S. Rodrigues and Josefa N. S. Pandeirada have contributed equally to this work

Introduction

Humans have time-of-day fluctuations (peaks and troughs) that affect various aspects such as cognitive performance (e.g., Schmidt, Collette, Cajochen, & Peigneux, 2007), social behavior and intellectual performance (e.g., Goldstein, Hahn, Hasher, Wiprzycka, & Zelazo, 2007), mental and physical health (e.g., Randler, 2011). This is an individual difference and people can be classified as morning, intermediate, or evening-types (e.g., Gelbmann et al., 2012), corresponding to peaks of performance in the morning, middle of the day, or evening, respectively. The morningness-eveningness preference (or chronotype) gradually changes throughout development, and is determined by genetic, biological and social factors (Roenneberg et al., 2004). Other factors also influence circadian rhythms, such as the geographical location (e.g., rural *vs*. suburban *vs*. urban; Randler, 2011), light exposure and sports (Gelbmann et al., 2012), and even season of birth (Natale & Di Milia, 2011).

During childhood, most individuals show strong morning tendencies, but a shift towards eveningness occurs in adolescence, approximately between 12-14 years (Díaz-Morales, de León, & Sorroche, 2007; Tonetti, Fabbri, & Natale, 2008). This tendency for higher eveningness continues throughout adolescence, peaking around the 20s (e.g., Roenneberg et al., 2004). However, this peak tends to occurs earlier for females (17 years), than for males (around 21 years; see Tonetti et al., 2008), because pubertal manifestations also occur earlier in the former (for a review, see Adan et al., 2012). Other studies have reported somewhat different results indicating that females are more morning-oriented than males (Randler & Díaz-Morales, 2007; Roenneberg et al., 2004), or that there are no significant differences between the sexes (e.g., Díaz-Morales et al., 2007; Russo, Bruni, Lucidi, Ferri, & Violani, 2007).

Understanding the morningness-eveningness preferences in adolescence is important for developmental reasons and also because of its influence in various areas as summarized next. The mismatch between cronotype and the schedule organization of the daily activities (including school activities), affect negatively the adolescents' social behavior, and their physical and mental well-being (Hahn et al., 2012). Additionally, adolescents with eveningness preference are most likely to develop mood and anxiety problems (Gau et al., 2007; Randler, 2011), to reveal attentional difficulties and to get involved in substance use (e.g., Gau et al., 2007), to have more aggressive behaviors and more frequent behavioral problems of clinical significance (e.g., Goldstein et al., 2007), to report irregular sleep-wake schedules (e.g., Mateo, Díaz-Morales, Barreno, Prieto, & Randler, 2012; Russo et al., 2007), and to have higher suicidality (e.g., Gau et al., 2007). These adolescents have also showed poorer academic performance and lower interpersonal skills (e.g., Goldstein et al., 2007). On the other hand, morning-oriented adolescents seem to be protected for adolescent psychopathology (see Gelbmann et al., 2012), and are less impulsive and more persistent which positively influences school achievement (e.g., Adan, Natale, Caci, & Prat, 2010). These data clearly establish the relevance of studying this individual characteristic in this age group.

Tools to evaluate the chronotype in children (aged between 4-11 years), and the age group between 15-94 years already exist in Portugal, namely the Children's Chronotype Questionnaire (CCTQ; Couto et al., 2014) and the Morningness-Eveningness Questionnaire (MEQ; Silva et al., 2002), respectively. However, no instruments to measure it in adolescents (12-14 years) exist for our population. Given the wide importance of understanding this variable as just briefly reviewed, such an instrument is essential. The goal of this study was to translate and adapt the MEQ (Horne & Ostberg, 1976) for Portuguese adolescents (henceforward aMEQ), providing preliminary psychometric validity data as well as various cut-off points[1].

Method

Participants

The sample was composed of 300 (167 female) adolescents aged 12-14 years (*M*=13.17, *SD*=0.74) recruited from several schools (80% public and 20% private schools) from the district of Aveiro (Portugal). The study was authorized by the Portuguese Directorate-General for Education and by the school directors. Informed consent was obtained from the parents of the participants and also from the adolescents before participation.

1. We should note that the MEQ is used extensively as a self-report questionnaire to assess circadian preferences, as recognized by researchers (e.g., Tonetti et al., 2008). However, other instruments exist to assess this characteristic in adolescents as can be seen in publications of the area (e.g., Hahn et al., 2012; Mateo et al., 2012; Randler, 2011).

Instrument

Morningness-Eveningness Questionnaire (Horne & Östberg, 1976). This questionnaire is composed of 19 items aimed to measure whether a person's peak of alertness occurs in the morning, the afternoon/evening or in an intermediate time of the day. Fourteen questions present four response options and five questions require responses using hourly scales. Scores range from 16 (eveningness) to 86 (morningness) points. The original questionnaire was translated to European Portuguese by 2 researchers highly proficient in English and then reviewed by an English professor. Next, 24 adolescents (13 female) aged 12-14 years (*M*=12.75, *SD*=0.85) participated in a think-aloud protocol in small group sessions which resulted in small vocabulary adjustments to improve comprehension of the aMEQ. These procedures ensure the content validity of the instrument.

Procedure

The questionnaire was administrated in groups of 10-26 participants under the supervision of one of the authors in sessions lasting approximately 20 minutes.

Results

On average, the aMEQ score was 52.49 (*SD*=7.66), and ranged between 29 and 76 points. The scale was left skewed with -.297 (error=.141), and kurtosis was .486 (error=.281); however, the Kolmogorov–Smirnov Z of .967 revealed a good fit with a normal distribution curve (*p*=.307).

The percentages of participants characterized as being of the morning, intermediate and evening-types are presented in Table 1 using different cut-off points typically used: mean ± 1*SD*, percentiles 10 and 90, and the less restrictive percentiles 20/80. These data are presented for the entire sample, and also separately for the female and male participants. The majority of the adolescents are of the intermediate type, followed by the morning-type; the evening-type was the least frequent in our sample.

Table 1

Percentages of participants identified with the morning, intermediate, and evening-type. Data are presented for the overall sample and separately for females and males according to different cut-point options.

	Criteria	Cut-off points	Morningness-Eveningness Preferences		
			Morning	Intermediate	Evening
Overall sample	mean±1*SD*	45/60	17.3%	69%	13.7%
	Perc 10/90	43/61	14.7%	76%	9.3%
	Perc 20/80	46/59	21.7%	62%	16.3%
Females	mean±1*SD*	44/60	18.6%	70.7%	10.8%
	Perc 10/90	43/61	15%	76%	9%
	Perc 20/80	46/59	22.2%	62.3%	15.6%
Males	mean±1*SD*	45/60	15.8%	71.4%	12.8%
	Perc 10/90	42/61	14.3%	76.7%	9.0%
	Perc 20/80	47/59	21.1%	60.2%	18.8%

Note: the cut-points for the males and females were determined using the data from the participants of each sex. “Perc 10/90” and “Perc 20/80” refer to percentiles 10/90 and 20/80, respectively.

Using the classification based on the cut-off points of 20/80 for each sex, a chi-square test revealed no statistically significant differences in the proportion of morning, intermediate, and evening-types, $\chi^2(4, N=300)=.550$, $p=.760$, $C=.043$, $p=.760$. A *t* test for independent samples using the total aMEQ score, also revealed a non-statistically significant difference between males ($M=52.77$, $SD=7.42$) and females ($M=52.26$, $SD=7.86$), $t(298)=.574$, $p=.567$. To further explore sex differences we submitted the results of each item to a Mann-Whitney U test. Significant results were obtained in the following items: item 3, where males mentioned to be more dependent of an alarm clock if they needed to wake up at a given time in the morning ($U=8013.5$, $p<.001$); item 6, with males reporting to have more appetite during the first half hour after waking up in the morning ($U=8704.5$, $p<.001$); item 13, with males noting they would sleep later than usual if they were free to do so after going to sleep later than usual the night before ($U=8847.5$, $p<.01$); item 10, were females reported feeling tired and needing to sleep earlier than males (*U*=8371, *p*<.001); and, item 12, with females reporting to feel more tired if they went to bed at 11pm than males (*U*=9328, *p*<.01).

Regarding age, Pearson's correlation suggests that morningness decreases with age, although the result did not reach statistical significance (*r*=–.034, *p*=.556). When this analysis was performed separately for each sex, we also obtained non-significant correlations in both cases (lower *p*=.261), although the relation between age and chronotype was positive for females (*r*=.016) and negative for males (*r*=–.098).

According to Cronbach's alpha value, the reliability of the scale was .692, a level that can be considered marginal (according to Nunnally & Bernstein, 1994, an adequate value should be >.70). Considering that the validity of Cronbach's alpha as a measure of reliability has been questioned (e.g., Osburn, 2000) we also calculated the Composite Reliability (*CR*) as defined by Fornell and Larcker (1981) and suggested by Marôco (2014). aMEQ obtained a *CR* of 0.702, a suitable indicator of construct reliability confirming that all items are consistent manifestations of a latent factor (Hair, Anderson, Tatham, & Black, 1998).

Discussion

The aim of this study was to translate, adapt and establish the psychometric validity of the Morningness-Eveningness Questionnaire (Horne & Ostberg, 1976) to Portuguese adolescents (12-14 years), providing the first preliminary valid instrument to researchers interested in this topic and age group. As reviewed in the introduction, circadian preferences in adolescents have various potential implications and should be considered thoroughly. Overall, the psychometric assessment of the instrument was positive, as indicated by a borderline Cronbach's alpha and an appropriate *CR* score (see Hair et al., 1998).

The distribution of the circadian preferences in our sample was similar to what has been presented in studies conducted in countries of latitude comparable to Portugal (e.g., Spain and Italy). For example, Díaz-Morales et al. (2007) reported for a sample of 12-16 years Spanish adolescents the percentages of 22.8%, 54.6%, and 22.6% for the morning, intermediate and evening orientations, respectively. Also in Spanish adolescents aged 12-16 years, Mateo et al. (2012) indicated percentages of 29.1%, 42.9% and 28% for the morning, intermediate and evening-type, respectively. These two studies reported similar proportions for the morning and evening-types while in our study we obtained a slightly higher percentage of morning as compared to the evening-type. This could be due to the inclusion of older adolescents in their samples given that we know there is a tendency for eveningness preferences to increase throughout adolescence (Roenneberg et al., 2004). A study conducted with Italian 8-14 years adolescents, reported percentages of 11% for both the morning and evening-types (Russo et al., 2007). Another study with 13 years Italians reported overall percentages of 18.7%, 75.97% and 5.4% for the morning, intermediate and evening-types, respectively (average values from their control groups; Natale et al., 2005). In our sample we obtained higher percentages of both the evening and morning-types as compared to these two studies. We should note that, in the first Italian study, the sample was younger than ours which could motivate these disparate results. Additionally, circadian preferences can be influenced by other factors as noted in the introduction. In our study we tried to gather a sample that would be representative of several settings (e.g., sub-urban *vs.* urban environment; public *vs.* private schools) to assure a better characterization of the circadian preferences of Portuguese adolescents.

Similar to other studies, no differences in circadian preferences were found between boys and girls (e.g., Díaz-Morales et al., 2007; Russo et al., 2007). However, some differences were obtained in the item-by-item analysis. Boys reported to be more dependent of on alarm clock if they needed to wake up at a given time in the morning, to have more appetite during the first half hour after waking up in the morning, and to sleep later than usual if they were free. On the other hand, girls reported to be more tired overall and if they went to bed at 11 pm, and also needing to sleep earlier than males. These results are in line with previous studies that have demonstrated that females prefer going to bed earlier than males, and also have longer sleeping periods (e.g., Mateo et al., 2012; Tonetti et al., 2008).

Regarding the relation between age and chronotype, in agreement with the reviewed literature, we found a descriptive tendency for morningness to decrease with age (e.g., Díaz-Morales et al., 2007). However, in our sample this relation occurred predominantly for the males with the opposite occurring for the females, but only at a descriptive level. The failure to obtain a clear relation between these variables might be due to a younger sample in our study as compared to the other studies.

We should note that our sample was from a restricted area of Portugal and further studies should establish the validity of the questionnaire to our population. Moreover, its criterion validity with external methods, such as body activity and temperature measures, as well as the study of its temporal stability, is warranted to firmly establish this questionnaire as a reliable measure of chronotype in the studied age group.

The present results reveal that school start time is incompatible with the circadian preference of more than 10% of our adolescents (i.e., school jetlag; Díaz-Morales et al., 2007), a mismatch that can have damaging consequences in several domains as reviewed before. We present a valid instrument that other researchers can now use to explore other aspects suggested to be related to chronotype in Portuguese adolescents, such as the influence of the congruency between the school activity schedules and the chronotype preferences on the adolescents' academic performance or social adjustment. In the clinical setting, studies could explore if employing intervention programs during the preferred activity period of the adolescents would result in more effective outcomes. Besides contributing to the understanding of circadian rhythms throughout development, studies of this individual difference might support the development of specific measures to promote an overall quality of live and successes of the adolescents.

Acknowledgments

Pedro F. S. Rodrigues, Pedro Bem-Haja and Josefa N. S. Pandeirada were supported by the Portuguese Foundation for Science and Technology (Fellowships SFRH/BD/84279/2012 and SFRH/BD/85928/2012, and research grant IF/00058/2012). A special acknowledgment is made to the group of schools from Águeda, Águeda Sul, Aveiro, Gafanha da Nazaré, Murtosa, Oliveira do Bairro, and Colégio D. José I, for their collaboration in this study.

References

Adan, A., Archer, S.N., Hidalgo, M.P., Milia, L.D., Natale, V., & Randler, C. (2012). Circadian typology: a comprehensive review. *Chronobiology International*, *29*, 1153-1175. doi:10.3109/07420528.2012.719971

Adan, A., Natale, V., Caci, H., & Prat, G. (2010). Relationship between circadian typology and functional and dysfunctional impulsivity. *Chronobiology International*, *27*, 606-619. doi:10.3109/07420521003663827

Couto, D.A., Gomes, A.C.A., De Azevedo, M.H.P., Bos, S.C., Leitão, J.A., & Silva, C.F. (2014). The European Portuguese version of the children chronotype questionnaire (CCTQ): Reliability and raw scores in a large continental sample. *Journal of Sleep Research, 23*, 160-160.

Díaz-Morales, J.F., de León, M.C.D., & Sorroche, M.G. (2007). Validity of the morningness-eveningness scale for children among Spanish adolescents. *Chronobiology International, 24*, 435–447. doi:10.1080/07420520701420659

Fornell, C., & Larcker, D. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*, 39-50. doi:10.2307/3151312

Gau, S.S.-F., Shang, C.-Y., Merikangas, K.R., Chiu, Y.-N., Soong, W.-T., & Cheng, A. T.-A. (2007). Association between morningness-eveningness and behavioral/emotional problems among adolescents. *Journal of Biological Rhythms*, *22*, 268-274. doi:10.1177/0748730406298447

Gelbmann, G., Kuhn-Natriashvili, S., Pazhedath, T.J., Ardeljan, M., Wöber, C., & Wöber-Bingöl, Ç. (2012). Morningness: Protective factor for sleep-related and emotional problems in childhood and adolescence? *Chronobiology International*, *29*, 898–910. doi:10.3109/07420528.2012.686946

Goldstein, D., Hahn, C.S., Hasher, L., Wiprzycka, U.J., & Zelazo, P.D. (2007). Time of day, intellectual performance, and behavioral problems in morning versus evening type adolescents: Is there a synchrony effect? *Personality and Individual Differences, 42*, 431-440. doi:10.1016/j.paid.2006.07.008

Hahn, C., Cowell, J.M., Wiprzycka, U.J., Goldstein, D., Ralph, M., Hasher, L., & Zelazo, P. D. (2012). Circadian rhythms in executive function during the transition to adolescence: the effect of synchrony between chronotype and time of day. *Developmental Science*, *15*, 408-416. doi:10.1111/j.1467-7687.2012.01137.x

Hair, J., Anderson, R., Tatham, R., & Black, W. (1998). *Multivariate Data Analysis.* (5 ed.). London: Prentice Hall.

Horne, J., & Ostberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International Journal of Chronobiology, 4*, 97-110.

Marôco, J. (2014). *Analysis of Structural Equations: Theoretical basis, software & applications*. Lisboa: ReportNumber.

Mateo, M.J.C., Díaz-Morales, J.F., Barreno, C.E., Prieto, P.D., & Randler, C. (2012). Morningness-eveningness and sleep habits among adolescents: Age and gender differences. *Psicothema, 24*, 410-415.

Natale, V., & Di Milia, L. (2011). Season of Birth and Morningness: Comparison Between the Northern and Southern Hemispheres. *Chronobiology International, 28*, 727-730. doi:10.3109/07420528.2011.589934

Natale, V., Sansavini, A., Trombini, E., José Esposito, M., Alessandroni, R., & Faldella, G. (2005). Relationship between preterm birth and circadian typology in adolescence. *Neuroscience Letters, 382*, 139–142. doi:10.1016/j.neulet.2005.03.004

Nunnally, J.C., & Bernstein, I.H. (1994). *Psychometric theory*. New York: McGraw-Hill.

Osburn, H.G. (2000). Coefficient alpha and related internal consistency reliability coefficients. *Psychological Methods, 5*, 343-355. doi:10.1037/1082-989X.5.3.343

Randler, C. (2011). Association between morningness–eveningness and mental and physical health in adolescents. *Psychology, Health & Medicine, 16*, 29–38. doi:10.1080/13548506.2010.521564

Randler, C., & Díaz-Morales, J.F. (2007). Morningness in German and Spanish students: A comparative study. *European Journal of Personality, 21*, 419-427. doi:10.1002/per.632

Roenneberg, T., Kuehnle, T., Pramstaller, P., Ricken, J., Havel, M., Guth, A., & Merrow, M. (2004). A marker for the end of adolescence. *Current Biology, 14*, R1038-R1039. doi:10.1016/j.cub.2004.11.039

Russo, P.M., Bruni, O., Lucidi, F., Ferri, R., & Violani, C. (2007). Sleep habits and circadian preference in Italian children and adolescents. *Journal of Sleep Research, 16*, 163-169. doi:10.1111/j.1365-2869.2007.00584.x

Schmidt, C., Collette, F., Cajochen, C., & Peigneux, P. (2007). A time to think: Circadian rhythms in human cognition. *Cognitive Neuropsychology, 24*, 755-789. doi:10.1080/02643290701754158

Silva, C.F., Silvério, J.M.A., Rodrigues, P.J.F., Pandeirada, J.N.S., Fernandes, S.M., Macedo, F.B., & Razente, S.N. (2002). The Portuguese version of the Horne and Ostberg morningness-eveningness questionnaire: Its role in education and psychology. *Revista Psicologia e Educação, 1*, 39-50.

Tonetti, L., Fabbri, M., & Natale, V. (2008). Sex difference in sleep-time preference and sleep need: A cross-sectional survey among Italian pre-adolescents, adolescents, and adults. *Chronobiology International*, *25*, 745-759. doi:10.1080/07420520802394191

Appendix 4

Pictures considered most appealing by each age group and equally appealing for the four age groups

| *Pictures used in the high-load visual environment* |

In this Appendix, we present the set of pictures considered most appealing to each age group, which was placed in the most "visible" position, that is in the first row counting from the bottom, the one closer to the laptop screen where most cognitive tasks would be displayed and performed. We also show the set of pictures considered to be equally interesting for the four age groups (common pictures).

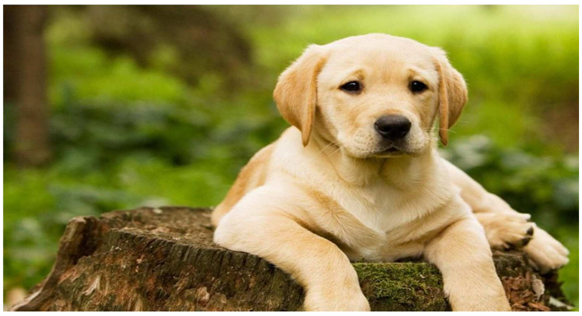
Children

Adolescents

Young adults

Older adults

Common pictures



Appendix 5

Counterbalancing Versions of the Experiment

Table 1

The eight possible counterbalancing versions of the environmental manipulation and of the cognitive tasks used in the study

	Order of environment		Order of cognitive task			
Participant#	High-load	Low-load	Corsi blocks	Go/no-go	Rey complex Figure	Selective response
1	1	2	1	2	3	4
2	1	2	2	3	4	1
3	1	2	3	4	1	2
4	1	2	4	1	2	3
5	2	1	1	2	3	4
6	2	1	2	3	4	1
7	2	1	3	4	1	2
8	2	1	4	1	2	3
(…)	(…)	(…)	(…)	(…)	(…)	(…)

Note: The first column corresponds to the participant number; the remaining columns indicate the order in which the environment was manipulated and the cognitive tasks were implemented. For example, participant# 1 performed the first session in the high-load surrounding environment, while the second session was realized in the low-load environment. In each of the sessions, the participant performed firstly the Corsi blocks, secondly the go/no-go, then the Rey Complex Figure and finally the selective response task. As for participant# 5, the first session occurred in the low-load environment whereas the second occurred in the high-load environment; the order of the tasks for this participant was the same as for participant# 1.

Appendix 6

Descriptive values of the results for all age groups
in all of the cognitive tasks

This Appendix reports the descriptive values for all of the considered variables of the cognitive tasks - go/no-go, choice reaction time, Rey Complex Figure, and Corsi block-tapping. The results are presented for each age group and by environmental condition.

Table 1

Go/no-go task: Means (and SDs) values obtained for the hits, false alarms, and reaction times for the hits in each age group and environmental condition.

	High-load environment	**Low-load environment**
% of hits		
Children***	84.90 (13.93)	90.12 (12.32)
Adolescents**	93.16 (9.07)	96.77 (3.72)
Young adults	98.14 (5.41)	98.61 (3.65)
Older adults**	61.16 (25.70)	70.67 (24.81)
% of false alarms		
Children	29.65 (16.67)	29.95 (17.96)
Adolescents***	20.48 (14.65)	12.87 (10.15)
Young adults	7.05 (5.06)	6.38 (5.47)
Older adults	10.47 (9.14)	9.47 (9.66)
Reaction times for the hits (ms)		
Children	378.70 (36.88)	377.55 (46.48)
Adolescents	333.08 (39.49)	337.61 (33.00)
Young adults	346.03 (28.24)	346.33 (29.47)
Older adults**	447.05 (63.43)	417.97 (74.32)

Notes: *** paired *t*-test with $p < .001$; ** paired *t*-test with $p < .01$.

Table 2

Choice reaction time task: Means (and SDs) values obtained for the correct responses, errors, and reaction times for the correct responses in each age group and environmental condition.

	High-load environment	**Low-load environment**
% of correct responses		
Children*	73.10 (17.05)	78.27 (15.45)
Adolescents**	83.95 (17.58)	91.69 (6.46)
Young adults	94.05 (6.94)	94.15 (8.64)
Older adults***	47.34 (23.49)	60.06 (25.61)
% of errors		
Children	10.94 (5.95)	12.51 (9.12)
Adolescents**	7.99 (7.48)	5.48 (5.29)
Young adults	2.73 (2.19)	2.97 (2.52)
Older adults*	6.93 (6.15)	5.70 (5.29)
Reaction times for the correct responses (ms)		
Children*	378.45 (48.81)	363.82 (57.17)
Adolescents	347.01 (34.23)	345.62 (33.84)
Young adults	359.79 (30.07)	354.45 (32.02)
Older adults	439.16 (65.77)	429.02 (48.39)

Notes: *** paired *t*-test with $p < .001$; ** paired *t*-test with $p < .01$; * paired *t*-test with $p < .05$.

Table 3

Corsi block-tapping: Means (and SDs) values obtained for the memory span in each age group and environmental condition.

	High-load environment	Low-load environment
Memory span		
Children**	4.39 (.95)	4.70 (.89)
Adolescents***	5.06 (1.12)	5.56 (.93)
Young adults	5.58 (.87)	5.56 (.89)
Older adults***	3.86 (.90)	4.56 (.73)

Notes: *** paired *t*-test with $p < .001$; ** paired *t*-test with $p < .01$.

Table 4

Rey Complex Figure: Means (and SDs) values obtained for the copy and immediate recall in each age group and environmental condition.

	High-load environment	Low-load environment
Copy		
Children	31.74 (4.42)	32.13 (4.23)
Adolescents	32.88 (2.60)	33.07 (2.88)
Young adults	34.43 (1.84)	34.66 (1.16)
Older adults	26.30 (5.56)	26.66 (5.19)
Immediate recall		
Children**	21.75 (6.13)	23.76 (6.14)
Adolescents	28.58 (3.22)	29.09 (3.45)
Young adults	29.30 (5.25)	29.02 (5.80)
Older adults	18.35 (5.80)	19.06 (5.61)

Note: ** paired *t*-test with $p < .01$.

Appendix 7

Descriptive values of state-anxiety, depression, and chronotype

Table 1

Means values (and SDs) obtained in the assessment of state-anxiety (average from the two sessions) and depression. The score range of instrument is also indicated as well as the cut-off for each case.

	Anxiety	**Depression**
Children	23.23 (3.89) (score range: 20-60) (cut-off: 35.13)	3.70 (3.52) (score range: 0-54) (cut-off: 15.45)
Adolescents **[13-14 YO]**	26.36 (4.29) (score range: 20-60) (cut-off: 35.13)	5.38 (6.21) (score range: 0-54) (cut-off: 18.97)
[15-17 YO]	25.61 (4.63) (score range: 20-80) [cut-off: 46.48 (M)/49.17 (F)]	
Young adults	32.17 (6.19) (score range: 20-80) [cut-off: 45.53 (M)/47.46 (F)]	8.95 (7.72) (score range: 0-63) (cut-off: 20.16)
Older adults	6.02 (5.09) (score range: 0-20) (cut-off: ≥8)	11.23 (3.65) (score range: 0-27) (cut-off: >11)

Notes: For detailed information of each instrument used in each age group, see Chapter 2. M – Male; F – Female. In all instruments, higher values correspond to higher anxiety/depression.

Table 2

Means values (and SDs) obtained in the assessment of chronotype. The score range of each instrument is also indicated as well as the cut-off that classifies individuals into morning-, intermediate-, and evening-type.

Children	**[8-11 YO]**	28.84 (4.25) (score range: 10-49) (≤ 23: morning-type; 24-32: intermediate; ≥ 33: evening-type)
	[12 YO]	55.67 (4.87) (score range: 16-86) (≤ 44: evening-type; 45-59: intermediate; ≥ 60: morning-type)
Adolescents	**[13-14 YO]**	53.03 (5.01) (score range: 16-86) (≤ 44: evening-type; 45-59: intermediate; ≥ 60: morning-type)
	[15-17 YO]	42.41 (5.02) (score range: 13-73) (≤ 42: evening-type; 43-53: intermediate; ≥ 54: morning-type)
Young adults		41.19 (6.73) (score range: 13-73) (≤ 42: evening-type; 43-53: intermediate; ≥ 54: morning-type)
Older adults		57.55 (6.34) (score range: 13-73) (≤ 42: evening-type; 43-53: intermediate; ≥ 54: morning-type)

Notes: For detailed information of each instrument used in each age group, see Chapter 2.

Table 3

Frequency Table: Number of participants in each chronotype group.

	Synchrony-chronotype	**Asynchrony-chronotype**
Children	20	44
Adolescents	24	40
Young adults	25	39
Older adults	13	51

Notes: The *synchrony-chronotype group* includes the individuals for whom the period of the session was coincident with the best performing period of the individual (e.g., a morning-type participant performed the tasks in the morning period), and the *asynchrony-chronotype group* included the cases in which the moment of the session was not coincident with the best performing period of the individual (e.g., a morning-type participant performed the tasks in the evening period).