Universidade de Aveiro
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ESTUDO DA COMPONENTE COMPORTAMENTAL DO SISTEMA IMUNITÁRIO COMPORTAMENTAL ATRAVÉS DO JOGO CYBERBALL

EXPLORING THE BEHAVIORAL COMPONENT OF THE BEHAVIORAL IMMUNE SYSTEM THROUGH THE CYBERBALL GAME

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Psicologia da Saúde e Reabilitação Neuropsicológica, realizada sob a orientação científica da Doutora Josefa Pandeirada, Equiparada a investigadora principal do Departamento de Educação e Psicologia da Universidade de Aveiro.

o júri

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palavras-chave

sistema imunitário comportamental, ameaça de contaminação, cyberball, componente comportamental

resumo

O Sistema Imunitário Comportamental [BEH] é um conjunto complexo de mecanismos psicológicos, desenvolvido para proteger o organismo contra potenciais ameaças de contaminação, através de estratégias emocionais (nojo), cognitivas (atenção ou memória) e comportamentais. O *Cyberball* é um jogo de lançamento da bola, em que um jogador real interage com dois jogadores virtuais, sendo os participantes instruídos que os mesmos são reais. A presente investigação teve como objetivo explorar qual a influência das características dos jogadores virtuais, em particular características relacionadas ou não com doenças, no comportamento dos participantes. Para além disso, procurou-se explorar se este comportamento poderia ter sido orientado por um efeito de reciprocidade e pelo número de vezes que o participante recebeu a bola de cada jogador virtual. Os participantes foram distribuídos por diferentes grupos de contaminação: jogavam (1) com um jogador saudável e um jogador doente; (2) com dois jogadores saudáveis; ou (3) com dois jogadores doentes. Os resultados mostraram que os participantes, que receberam o mesmo número de lançamentos dos jogadores virtuais, completaram uma parte do jogo e foram distribuídos na condição doente-doente (“ranho” *vs*. “diarreia”), lançaram a bola mais vezes a favor do segundo jogador e reciprocaram mais vezes a favor mesmo (comparativamente ao primeiro jogador). Quando os participantes receberam a bola mais vezes de um dos jogadores virtuais, ou completaram o jogo na sua totalidade, não foram observadas preferências no lançamento da bola. Este estudo sugere que o *Cyberball* pode ser utilizado para explorar a componente comportamental do BEH. Para além disso, os resultados observados contribuem para compreender os padrões do comportamento humano quando este é exposto a uma potencial fonte de contaminação.

keywords behavioral immune system, contamination threat, cyberball, behavioral component

abstract

The Behavioral Immune System is a complex suite of psychological mechanisms designed to protect the organism from potentially dangerous microorganisms, through emotional, cognitive, and behavioral strategies. This research proposes that, under a potential contamination situation, humans are guided to adopt avoidance behavior strategies towards the potential source of contamination. This was tested using an online game known as *Cyberball*, a ball-tossing game where three players must throw a ball to each other. Different participants played the game with different virtual players who differed on their health status. In particular, different groups of participants played the game with one healthy and one sick virtual player; two healthy virtual players; or two sick players. We hypothesized that participants on the healthy-sick game condition would avoid tossing the ball to the sick player, while participants on a condition of equal descriptors would not report differences on tosses. Moreover, we explored if the response of participants were based on reciprocity (rather than on the associated descriptors) and on the number of throws received from the virtual players. Our results revealed that participants who have been set to play with both sick virtual players (running nose *vs*. diarrhea), completed one part of the game and received an equal number of throws from the virtual players, displayed heightened avoidance behavior towards the first player, and reciprocated more often to the second player. On the other hand, when participants received the ball a different number of times from each player, or completed the game, no significant effects were obtained. Our study suggests that the Cyberball game can be used to explore the behavioral component of the Behavioral Immune System. Furthermore, our findings contribute to understand how human behavior is guided to overcome when set on a potential contamination of disease condition.

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List of abbreviations

BIS	Biological Immune System
BEH	Behavioral Immune System
GA	Germ aversion
HH	Health-health contamination group
HS	Health-sick contamination group
PI	Perceived infectability
PVDS	Perceived Vulnerability Disease Scale
SS	Sick-sick contamination group

1. Introduction

Throughout animal evolution, different species have developed fitness-related behaviors to guarantee their survival. One example would be the well-known avoidance behaviors towards life-threatening stimuli, like predators or dangerous infectious microorganisms (Oaten et al., 2009). About the last, humans have been facing selective pressure from pathogens, in the past with bubonic plague and now with coronavirus disease 2019. Because of this continuous exposure to life-threatening microorganisms (regardless of the fact that we are under a global pandemic crisis), a complex defense system that could learn, adapt, and answer to those dangers evolved (Oaten et al., 2009; Schaller, 2016) – known as biological immune system (BIS). This sophisticated mechanism is designed to detect the intrusion of a pathogenic agent (viz., virus or parasite), destroy it and registry of its attributes in the immunological memory for a faster and more effective response in a future contact (Mueller & Rouse, 2008). Despite the very important role played by the BIS, Schaller (2016) enumerates some disadvantages: (i) the exhaustive use of metabolic resources in the anti-inflammatory response; (ii) the consequences of these responses, such as body exhaustion (e.g., fever and tiredness result from the action of the BIS and not from the pathogen itself); and (iii) the BIS activation occurs when the pathogen is already on the organism.

With the costly functioning of the BIS, Schaller and Park (2011) suggested that the human species has developed a motivational mechanism that regulates the contact with potential sources of infection and consequently helps to protect the organism, known as Behavioral Immune System (BEH). Because humans cannot detect the presence of a virus, given its microscopic size, they look for visual or olfactory cues that signal a possible danger. When the treat is perceived, emotional (e.g., disgust), cognitive (e.g., allocation of attention or memory recall) and behavioral (e.g., evasive responses) strategies are activated to avoid potential contagion (Schaller & Park, 2011). The search of those visual or olfactory cues makes the BEH work in an exacerbated way; that is, not only does it react to real cues of contamination, but it also becomes hypervigilant and reacts to cues that do not pose any infection danger (i.e., obesity, odors, and facial marks; Murray & Schaller, 2016). This phenomenon is known as the “smoke detector principle”. When an observer perceives cues to detect the risk of danger, two types of error can occur: (i) a false positive error, where it is mistakenly inferred a risk of danger, when there is no real danger, or (ii) a false negative error, where it is mistakenly inferred the inexistence of danger, when there is a danger risk (Nesse, 2005). Although the general principle is to act trough a false error, both types of errors have different outcomes. While the unnecessary avoidance of an object (false-positive) is an adaptive manifestation to avoid even more costly errors (e.g., exposure to the contaminated stimuli), the inability to identify a potential infecting agent (false-negative) may cause unnecessary and fatal consequences, such as death (Schaller, 2016). In short, we can establish the analogy of the smoke detector with the functioning of the BEH, i.e., it is calibrated to avoid errors in the identification of pathogens and, as a result, biased behaviors are adopted to prevent the danger of contamination (Murray & Schaller, 2016; Schaller & Park, 2011).

BEH is activated through disgust, an emotion characterized by the feeling of rejection or avoidance from provocative stimulus (e.g., animals, source of contamination or disease, or culturally unacceptable behaviors), through cross-cultural behaviors or facial expressions (Rozin et al., 2016). In the case of risk of contamination or disease, disgust can be activated through the following stimuli: body secretions; insects; sexual or hygiene behaviors; and dead bodies (Oaten et al., 2009). Schaller (2016) states three pieces of evidence that support the idea that disgust is as an activation tool of the BEH: (i) for two similar stimuli, disgust is activated for one that presents a stimulus that induces contamination danger; (ii) contamination-related stimuli induce higher levels of disgust than other emotions; and (iii) contamination-related stimuli provoke exaggerated responses of disgust when individuals are vulnerable to contamination.

The threat of contamination can also be perceived when a certain object was close to a disgusting stimulus or it has the same appearance, and therefore, it is believed that this object has been infected too. This is known as the “law of contagion” and “law of similarity”, respectively – both laws of sympathetic magic (Rozin et al., 1986). This perceived magical contamination causes the activation of exaggerated avoidance behaviors for stimuli that do not impose any danger, because it is believed that the information from the disgusting stimulus is transferred to the harmless stimulus, when it is in contact (e.g., people refuse to drink a juice that has been in contact with a sterile cockroach) or it has a similar appearance (e.g., people refuse to eat a chocolate that looks like feces; Rozin et al., 2016). The above-mentioned evidence contributes to understand how disgust can work as a defense mechanism towards disease-related stimuli and, additionally, it supports the smoke detector principle and how it works: we are guided by false positive errors in order to prevent potential contamination of the organism. That said, we can suggest the existence of a relationship between what is the disease activation and the BEH, where the first still contributes as an adaptive mechanism which suffered selection pressures to protect the organisms from potential disease-related sources (Oaten et al., 2009; Tybur et al., 2013; Tybur et al., 2020).

Although there is a solid theoretical basis for the BEH activation through the emotion of disgust, there are other mechanisms that help to protect the organism, such as cognitive strategies, viz., attention and memory (Ackerman et al., 2009; Tybur et al., 2014). Humans are exposed to a multitude of visual stimuli simultaneously and it is expected that attention will be directed to those who are perceived as threatening. This idea is considered adaptive because the detection of danger promotes the survival of the species (Ohman et al., 2001, cit. in Berdica et al., 2018). For example, when two pictures are presented simultaneously, one being a neutral stimulus (e.g., butterflies) and the other a fear-related stimulus (e.g., spiders or angry faces), it has been verified that the fear-related ones are those that receives more attention first (Berdica et al., 2018). That said, we can hypothesize that, if there is a biased attention towards threatening stimuli, then there might be a biased attention against disease or contamination-related stimuli – in fact, such suggestion has already received empirical support. Ackerman and collaborators (2009) have reported that disfigured faces that are perceived as risk of disease retain more attention than neutral faces. There is also evidence that there is a greater attentional bias for disgust-related stimuli (e.g., body secretions or cockroaches), when compared to fear-related stimuli (e.g., disasters or threats from humans or animals) or neutral stimuli (e.g., coffee machine or books; Chapman et al., 2013; Perone et al., 2020; van Hoff et al., 2013). In short, there is empirical support for a greater allocation of attention to disgust-related stimuli vs. other stimuli, which would ensure a more efficient functioning of the BEH, preventing the contact with potential sources of disease and contamination.

Regarding the second cognitive process, memory, Nairne and Pandeirada (2008) proposed the concept of "adaptive memory", the idea that memory evolved subject to selection pressures and became a tool that helped the human species to solve adaptive fitness-related problems. With this idea, we can suggest the existence of a memory advantage in identifying sources of contamination or disease. In fact, there is a growing literature that sustains the enhancement of memory on solving fitness-relevant problems: people remember better animate items when compared to inanimate ones (Nairne et al., 2013); females remember the faces of males when considered for a long-term mating as compared to when they are considered as a working partner (Pandeirada et al., 2017); or threatening stimuli are better remembered than neutral stimuli (Ackerman et al., 2009). Some studies have already recommended a memory enhancement towards disgust-related stimuli. For example, Croucher and collaborators (2011) found better recognition for disgust-related images when compared to frightening images. Later, Chapman and collaborators (2013) replicated this study with the same images and found that on short delays (recall task 10min after encoding), there was a small memory enhancement for the disgusting images (when compared to the fearful images), whereas on longer delays (recognition task after 45min to 1 week) there is a significant higher memory enhancement for the disgusting images over the fearful ones. There are also additional studies that have explored the effect of the memory in BEH based on the laws of sympathetic magic. For example, on the compilation of studies done by Fernandes and collaborators (2017, 2021), objects presented with contamination cues (e.g., objects being held by hands covered by vomit or diarrhea or presented along with a picture of a face / text description as a cue of sickness) are better remembered than neutral objects (e.g., touched by someone healthy or no evidence of sickness). In other hand, it has been tested if perceived vulnerability to disease is related to a mnemonic advantage for contamination. One would expect such advantage would be larger on participants who feel more vulnerable. In the exploratory analysis conducted by Fernandes (2020) no such relation was obtained, but the question is still open for debate. That said, there is empirical support that suggests that objects thought to be sources of contamination are better retained, which contributes to the idea that memory can help on the identification of fitness-threatening stimuli and, with that information, help to avoid a possible contamination or disease risk.

Finally, it comes the behavioral component of the BEH. It is suggested that the higher the sensibility for disgusting stimuli, the higher is the avoidance of the stimuli (Shook et al., 2019). Studies that use behavioral avoidance tasks based on disgust have observed that when the sensibility to contamination is higher (measured by self-report scales), the probability of interaction with the disgusting stimuli is lower, such as taking off from a bag an object touched by a sick person (Fan & Olatunji, 2013; Olatunji et al., 2014) or chew a grape, spit it to a cup and drink from it (Olatunji et al., 2008). Beyond these studies, there are few experiments that investigated the behavioral reactions and manifestations when the BEH is activated; we have only found two. Miller and Maner

(2011) were the first to describe behavioral observations, when their purpose of investigation was to understand whether the BEH compensates the BIS when the latter is weakened. Their experiment was based on the hypothesis that recent illness is associated with decreased approach and increased avoidance towards threatening stimuli (in this case, pictures of disfigured faces). Their procedure involved interacting with a joystick during the visualization of pictures with faces, where the participant was instructed to push (an avoidance response) or pull (an approach response) the joystick the fastest he/she could. It was observed that participants who had been recently ill allocated more attention and pushed the joystick faster when the disfigured face was displayed, compared to the healthy participants. Finally, the study of Shook and collaborators (2019), which explored how disgust is associated with general avoidance behavior. Their hypothesis (study 2) was that participants on the disgust condition would exhibit more avoidance behavior than those in the control condition. To start the experiment, participants on the disgust condition ate three disgust-flavored jellybeans (e.g., dog food), while participants on the control condition ate three neutral flavored jellybeans (e.g., chocolate). On both conditions, it was refused to participants the access to drink or eat other food if they found the jellybean taste on mouth unpleasant. Then, participants played the *BeanFest*, a game that assesses the approach-avoidance tendencies towards unfamiliar stimuli. In this game, players had to increase their point value by interacting with beans. Each bean had either a positive or a negative value associated, which was only learned if the player decided to interact with it. The researchers observed that participants on the disgust condition – when compared to those in the control condition – had higher avoidance tendencies (i.e., avoided more beans during the game) regardless the of the bean valence (i.e., positive or negative points).

The purpose of the current work was to fill the behavioral studies gap through the use of a virtual ball tossing game, known as *Cyberball*. On this game, participants play with two other virtual players, who participants should believe are real. In the traditional paradigm, *Cyberball* is used to induce ostracism and encourage feelings of social exclusion and rejection. The game originally starts with a brief inclusion phase, where the ball is tossed between the participant and the virtual players, until it becomes a continuous exclusion phase, during which the virtual players toss the ball only to each other until the game ends (Williams & Jarvis, 2006). After the game, it is predicted that participant reports lower levels of self-esteem, self-control, and sense of belonging, as compared to a point previous to the game (Gorman et al., 2017; Williams & Jarvis, 2006). In our study, we are mostly interested on the participants' behavior during the game, that is, on his/her decisions on who to throw the ball to (virtual player 1 or virtual player 2). Importantly to our purposes on analyzing the behavioral component under different conditions of potential contamination, the characteristics of the virtual players will be manipulated. Specifically, different participants will play the game with different players who differ on their health status (this will be described on 2.3. Procedure). We hypothesize that participants would: (i) avoid tossing the ball to the sick player (on the sick and healthy player condition); and (ii) when set on a condition where the two players have equal descriptors (either sick or healthy), no differences would occur on his/her throws. Additionally, we aim to explore the effect of reciprocity: to what extent the responses of participants are more influenced by the tendency to reciprocate than by the characteristics of the virtual players. Furthermore, we aimed to explore two individual differences usually associated to the BEH, namely the perceived vulnerability to disease and recency of illness.

2. Method

2.1. Participants

To determine the required minimum sample size for this experiment we used G*Power (3.1.9.7; Faul et al., 2007). It was estimated that, for three independent groups, and a within-subject variable with two levels, a sample size of 180 participants would have sufficient power ($1-\beta = .85$) at a significance level of $\alpha=.05$ to detect a medium effect size of $f = .25$. On this investigation, we were able to collect data from 117 participants (women = 78; 66.67%) who completed at least one part of the experiment, aged between 18 and 58 years old ($M_{age} = 28.77$, $SD = 9.96$). The complete task was performed by 83 participants (women = 53; 63.86%), aged between 18 and 54 years old ($M_{age} = 28.69$, $SD = 9.38$).

2.2. Materials

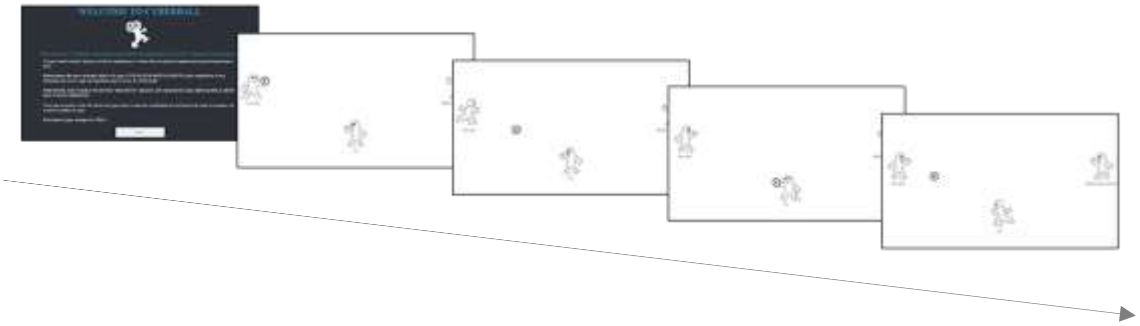
2.2.1. Cyberball

To manipulate the threat of disease aimed at activating the BEH, participants played the virtual game *Cyberball*. As stated above, it is a ball tossing game between the participant and two virtual players. The game is framed such that the participant is led to believe he/she is playing with two other real players who are engaged online in the same game. Three versions of contamination environment were created to manipulate the threat of disease (see. Table 2, section 2.3.). Virtual players were associated with a sickness descriptor (e.g., “I am vomiting”) and / or a healthy descriptor (e.g., “I am tall”).

To maintain the cover story (see 2.3. Procedure), participants were prompted to select three characteristics that could characterize them at the moment they were answering the survey. A set of descriptors was provided for this purpose (see section 2.2.2). Additionally, they were informed that one of their chosen characteristics would be randomly selected and displayed to the other players; similarly, they would see the other players’ selected characteristics (see Table 1 for descriptors). After reading the game instructions, a new screen was shown with three animated figures (plus their corresponding descriptors) and a ball.

The virtual player from the left started the first throw of the ball, and the receiver then throws it back to any of the players (see Figure 1 and supplementary material), until 20 throws have been done. The game stopped once the 20th toss was executed: an intentional interruption amidst the game was programmed, with a cover screen telling participants that game connection had been interrupted and would be recovered shortly. After 10 seconds, players are redirected to a new *Cyberball* frame to play the second part of the game, which consisted of the same number of trials. In our procedure, the virtual players had their targets randomly scheduled. The 20 throws, from both game parts, were programmed so that the participants were expected to receive and throw the ball six times.

Figure 1. Schematic representation of the *Cyberball* game (screenshots available at supplementary material)



2.2.2. Sick and healthy descriptors

A set of 15 descriptors was created, based on Fernandes et al. (2017) sentences. Nine of these descriptors were related to neutral characteristics of a person, while the other six described signs or symptoms of sickness (cf. Table 1).

Table 1.

Sick and neutral descriptors used on this experiment.

Neutral descriptors	Sick descriptors
I am happy	I feel feverish
I am tall	I have diarrhea
I have light hair	I am vomiting
I am short	I got a cold
I am excited	I keep coughing
I feel healthy	I have a running nose
I have light eyes	
I have dark hair	
I have dark eyes	

2.2.3. Visual mentalization questionnaire

A self-report questionnaire of visual mentalization skills was created to evaluate the participants' mental visualization skills (see below 2.3. Procedure). This was designed to be used as a cover story and was of no importance for the analysis. This questionnaire was adapted from the McKelvie's (1995) Vividness of Visual Imagery Questionnaire and consisted of two mental visualization situations (i.e., "Imagine a beach close to the sea on a hot day of summer" and "Imagine a garden with grass, shrubs and flowers"), each with four descriptive details (e.g., "appearance of water, waves and the skies" and "appearance of the garden", respectively). Participants were instructed to form a visual image of the situation, compare it with a real situation and rate how vivid their visual image was by answering each question on a 5-point Likert scale, ranging from "excellent" (4) to "poor" (0).

2.2.4. Perceived Vulnerability Disease Scale

The Perceived Vulnerability Disease Scale (PVDS; Duncan et al., 2009; Portuguese validation and translation by Ferreira et al., under preparation) is a self-report questionnaire of 12 items that assesses concerns about transmission of infectious diseases. The questionnaire includes two subscales: one that assesses the participants' beliefs about their susceptibility to infectious diseases (Perceived Infectability - PI), and another that assesses the discomfort under a situation where pathogens can be transmitted (Germ Aversion - GA). Participants answers to each item through a 7-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (7). While the original version provides good internal consistency for both scale (α=.87) and subscales (α_{PI}=.87 and α_{GA}=.74), the Portuguese version provides good internal consistency for subscales, α_{PI}=.80 and α_{GA}=.75. In the current study, the Cronbach's alpha coefficients for scale and subscales were α=.74, α_{PI}=.66 and α_{GA}=.69, respectively.

2.2.5. Self-report health status questionnaire

To evaluate participants' illness recency, three questions based on Miller and Manner (2011) were administered: (i) "In the last few days I haven't been feeling very well"; (ii) "Lately, I have been feeling sick"; and (iii) "I felt sick for the last week". Participants evaluated their health status through a 7-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (7). According to the authors, participants' health status was rated based on an average score; participants who scored 1 SD above the mean were classified as "recently ill", and those who scored 1 SD below the mean were classified as "not recently ill".

2.3. Procedure

All the procedure was implemented online through a survey platform hosted at the University of Aveiro (forms.ua.pt). Participants performed the experiment in a single session lasting approximately 10 to 15 minutes. Upon accessing the survey, participants were sequentially assigned to one of three game conditions (cf. Table 2): (HS) one virtual player was healthy and another was sick; (HH) both virtual players were healthy; and (SS) both virtual players were sick. The distribution was made by order of URL access, that is, if one participant accessed the survey and was attributed to condition HS, the next participant would be attributed to condition HH, and so on. At the start of the survey, participants were required to read and accept the survey requirements (i.e., it must be done on a computer) and to provide their informed consent to proceed with the experience. At this part, the real objective of the experiment (i.e., evaluation of the behavior under a possible condition of contamination) was not revealed, to guarantee their behavior while playing *Cyberball* was not biased. Instead, participants were told that the objective was to train and evaluate their mental visualization skills.

After consenting to participate, participants answered a short sociodemographic questionnaire about their sex and age. To keep the cover story of Cyberball, participants were requested to complete a visual mentalization questionnaire to evaluate their mental visualization skills. Once the cover task was completed, they were introduced to Cyberball; specifically, participants were told that they would be playing a game with two other players to train mental visualization skills. Instructions from Williams and Jarvis (2006) were adapted for this task. Before starting the game, participants were required to choose three descriptors among a list of provided descriptors (cf. Table 1) and informed that one of them would be randomly selected to be displayed to other players. This was done to cover the real purpose of the sickness/physical descriptors associated with the virtual players. Once the descriptors have been chosen, participants are redirected to the frame of *Cyberball* to play the first part of the game. At the 20th toss, the game was intentionally interrupted; a cover screen was then displayed, telling participants that game connection had been interrupted and that it would be shortly reestablished. After 10s on this screen, players are redirected to a new *Cyberball* frame to play the second part of the game. This intentional interruption on the game was introduced to ensure participants were paying attention to the game throughout the entire task.

Once the game was finished, participants were instructed to make a short description about the virtual players with whom they had been playing; this was done to verify if participants paid attention to the sick / healthy descriptors displayed on the other players. Then, participants were requested to answer the PVDS and the self-report health status questionnaires.

At the end of the survey, participants were asked if they paid attention to the whole experiment, where they had to choose between “Yes, keep my data” or “No, delete my data”. Finally, a reconsent form was displayed to participants, explaining the real goal of the experiment; participants were asked if, considering this new information they still consented their participation. In the event the participant would respond “No, delete my data”, their data would be deleted.

Table 2.

Descriptors associated to each player, on each group

	Player 1	Player 2
(HS) Healthy-sick	*"I am tall"*	*"I have a running nose"*
(HH) Healthy-healthy	*"I am tall"*	*"I have light hair"*
(SS) Sick-sick	*"I have a running nose"*	*"I have diarrhea"*

2.4. Data analysis

2.4.1. Overview

The statistical analyzes were performed using the software IBM SPSS, version 27 (IBM Corp., 2021). On this study, the assigned independent variables were the contamination group (HS, HH, and SS; between-subjects), game fulfillment and balance group (both variables detailed below). The dependent variables were the proportion of tosses performed by participants to each of the virtual players and the conditional probability of reciprocal tosses. The statistical tests used for the analyses were mixed and repeated-measures ANOVAs. On the first technique, the within-subjects variables used were the participants' tosses (i.e., ball tossed to player 1 or to player 2) and reciprocity (i.e., throw reciprocates to player 1 or to player 2), while for between-subjects variables, we considered the variables of contamination group and balance group. The latter technique was used to compare and verify significant differences within each group. The level of statistical significance was set at $p < .05$ for all analyses.

2.4.2. Probability of reciprocity

We predicted differences would occur on how participants would throw the ball to the virtual players considering their health status (i.e., sick or healthy). However, we then reasoned that the participants' decision on who they would throw the ball to (i.e., player 1 or player 2) might not be influenced solely by the nature of the virtual player associated characteristic (i.e., sick or healthy), but also by a matter of reciprocity; that is, there could be a tendency for participants to simply return the ball to the player from whom they received it, irrespectively of the player's condition. In order to assess this possibility, we calculated the probability of returning the ball to a given player considering it had been received from that player (see equation 1).

$$Probability\ of\ reciprocity = \frac{Reciprocal\ tosses\ to\ Player\ X}{Tosses\ received\ from\ Player\ X} \tag{1}$$

2.4.3. Game fulfillment

We prepared the statistical procedure to analyze the data from participants who completed both parts of the game (40 trials). However, as we were analyzing the data collected from Cyberball, we observed that some participants only completed one part of the game (20 trials). Because those participants played the game at least once, we considered the hypothesis their responses would still be influenced by the activation of the BEH (on the groups including at least one sick player). In order to maximize the obtained sample, and to explore if responding only to one part *vs.* the full sample would affect participants' responses, we analyzed separately the data from those participants who completed the game ("complete game"; N=83) and those who completed at least one part ("partial game"; N=117). For the first group, "complete game", we only considered the data from those participants who completed the 40 trials, this is, both parts of the game. For the latter group, "partial game", data from all the participants who played at least one part of the game were considered. In this group, we also included the data from the players who completed the game (40 trials), but only those corresponding to the first part of the game (i.e., the first 20 trials).

Additionally, for the "complete game" group, we evaluated the possibility that "parts of the game" (i.e., first 20 trials *vs.* second 20 trials) and balancing on the proportion of times the participant received the ball from each player could influence the results. Regarding the latter, during the data analysis, we observed that the proportion of times the participant received the ball from each of the virtual players was not always equal due to a program issue; Some participants received the ball one more time from player 1 than from player 2. As this could be a confounding variable, we created a categorial variable which identified the participants who received an equal or unequal proportion of tosses from each virtual player (i.e., balanced and unbalanced groups, respectively). This was set to test the possible effect this disproportion could cause on the participants' performance.

We started by carrying out an exploratory analysis of these variables on each of the dependent variables. As none of them interacted significantly with any of remaining variables, we only report the results considering the entire game (i.e., regardless of part of the experiment) and for all participants irrespective of balance. As for the data from participants with partial game, we obtained significant interactions with the variable "balancing". We conduced additional analysis to further explore such interactions.

Table 3 presents the sample sizes considered in each of the just described analyses.

Table 3.

Distribution of the sample based on the variables analyzed.

	Complete Game	Partial Game
	N	*N*
Equal tosses from virtual players		
Healthy-sick	15	28
Healthy-healthy	10	25
Sick-sick	9	18
Unequal tosses from virtual players		
Healthy-sick	17	13
Healthy-healthy	14	17
Sick-sick	18	16
Total	83	117

3. Results

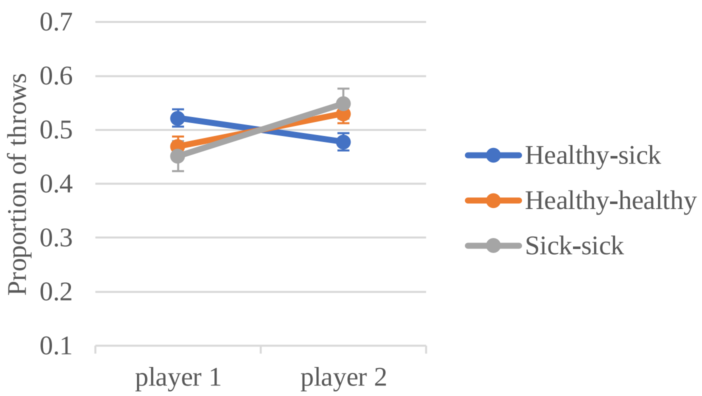
3.1. The impact of the players' descriptors on the participants' proportion of throws to players, considering game fulfillment and balanced groups

On this analysis, we started by analyzing the proportion of throws to players (player 1 *vs*. player 2) conducted by the participants, between the balanced groups (balanced *vs.* unbalanced groups, only on the partial game data) and the contamination groups (HS, HH and SS). We predicted that participants set on the HS group would throw more often the ball to the healthy player than to the sick player. For the other groups, HH and SS, we expected no differences on the proportion of throws to each of the virtual players.

3.1.1. Complete game

The results of the mixed ANOVA on the proportion of throws, with contamination group as the between-subjects variable, and receiving player as the within-subject variable, revealed a non-significant main effect of the receiving player, $F(1, 77) = 3.415$, $p = .068$, $\eta^2p = .042$, but a significant interaction on *Contamination group* x *Receiving Player*; $F(2,80) = 3.269$, $p = .043$, $\eta^2p = .076$ (see Figure 2 for the representation of results). To further clarify this interaction, we conducted a repeated-measures ANOVA within each group based on the contamination group variable, including receiving player as a within-subject variable. From this analysis, no effect was observed within groups; highest F value for effect on the SS group, $F(1, 26) = 3.054$, $p = .092$, $\eta^2p = .105$.

Figure 2. Mean proportion of throws to player 1 and to player 2 in each contamination group when the game was completed. Error bars represent standard error of mean.

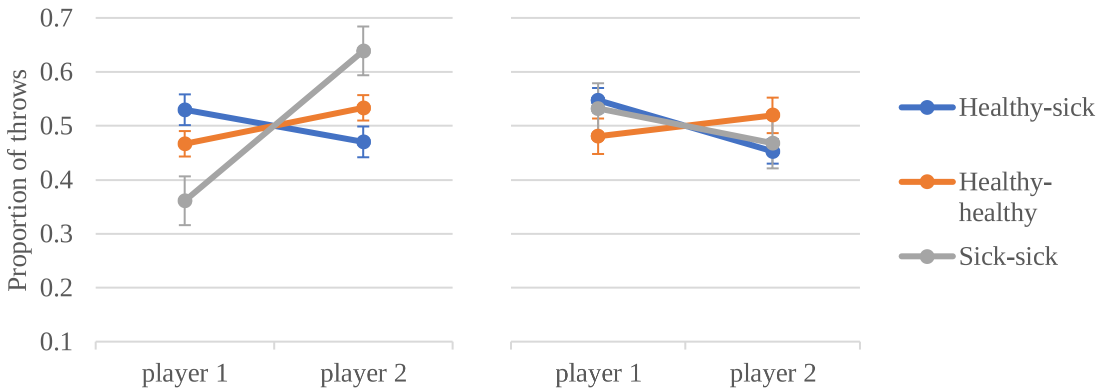


3.1.2. Partial game

Repeating the first analysis conducted for the complete sample on the proportion of throws, now considering the data from only one part of the game, with contamination group and balanced group as between-subjects variables, and receiving player as a within-subject variable, we verified that the main effect of receiving player was not statistically significance, $F(1, 111) = 0.925$, $p = .338$, $\eta^2p = .008$. All interactions reached significance levels: *Contamination group* × *Receiving player*, $F(2, 111) = 3.515$, $p = .033$, $\eta^2p = .060$; *Balanced group* × *Receiving player*, $F(1, 111) = 5.590$, $p = .020$, $\eta^2p = .048$; and *Contamination group* × *Balanced group* × *Receiving player*, $F(2, 111) = 3.178$, $p = .046$, $\eta^2p = .054$. To further clarify this later interaction, we conducted repeated-measures ANOVAs within each group based on the balanced group and contamination group variable, including receiving player as a within-subject variable (see Figure 3 for the representation of the results).

In the group in which the participant was set on the SS condition and received the ball equally from player 1 and player 2 (balanced group), the main effect of receiving player was significant, $F(1, 17) = 9.444$, $p = .007$, $\eta^2p = .357$; specifically, these participants sent the ball to player 2 more frequently than to player 1. For the remaining contamination groups, no significant main effects were obtained, highest F value for the main effect of receiving player on the HH group, $F(1, 24) = 2.000$, $p = .170$, $\eta^2p = .077$. Regarding the unbalanced group, no significant main effect was obtained, regardless the contamination group participants were set, highest F value for main effect of receiving ball when set on HS condition, $F(1, 12) = 4.280$, $p = .061$, $\eta^2p = .263$.

Figure 3. Mean proportion of throws to player 1 and to player 2 in each contamination group and by balanced group (equal throws on left and unequal throws on right) when the game was partially completed. Error bars represent standard error of mean.



3.1.3. Summary of analysis

For those participants who completed the game, the proportion of throws was significantly influenced by an interaction of contamination group and receiving player variables. Although this was verified, our analysis of throws within each contamination group did not reveal any significant differences; the interaction observed was explained by participants toss direction on the group HS *vs*. groups HH and SS. As observed on Figure 2, while participants on the HS group throw more often the ball to player 1, the opposite happened on the HH and SS groups.

Additionally, the distribution of the proportion of throws by the participants who completed at least one part of the game was significantly influenced by an interaction between contamination group, balanced group and receiving player. Those who were set on the SS contamination condition and received an equal number of tosses from players, threw the ball more often to player 2 than to player 1. No significant effects were observed on the HS and HH groups. Furthermore, no significant differences were obtained on the participants who received unequal number of throws from the virtual players.

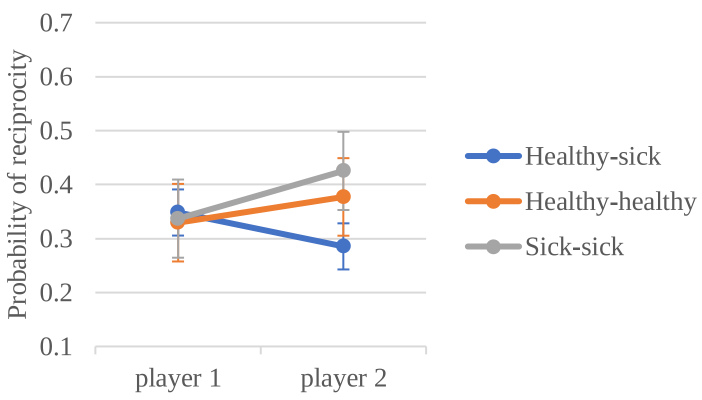
3.2. The impact of reciprocity as a bias on ball tossing

The analysis conducted on 3.1. was reproduced here, but now on the dependent variable of conditional probabilities of throws to player 1 and player 2 which would reflect a possible bias to reciprocate (see Table 3 for sample distribution).

3.2.1. Complete game

The results of the mixed ANOVA on the probability of reciprocity, with contamination group as a between-subjects variable, and receiving player as a within-subject variable, revealed a non-significant main effect of the receiving player, $F(1, 80) = 1.034$, $p = .312$, $\eta^2 p = .013$. However, the *Contamination group* × *Receiving player* interaction reached significance levels; $F(2, 80) = 3.844$, $p = .025$, $\eta^2 p = .088$ (see Figure 4 for the representation of results). We conducted a repeated-measures ANOVA within each contamination group, including the receiving player as the within-subject variable to clarify this interaction. From this analysis, no effect was observed within groups; highest F value for main effect on HS group, $F(1, 31) = 3.998$, $p = .054$, $\eta^2 p = .114$.

Figure 4. Mean probability of reciprocity to player 1 and to player 2 in each contamination group when the game was completed. Error bars represent standard error of mean.

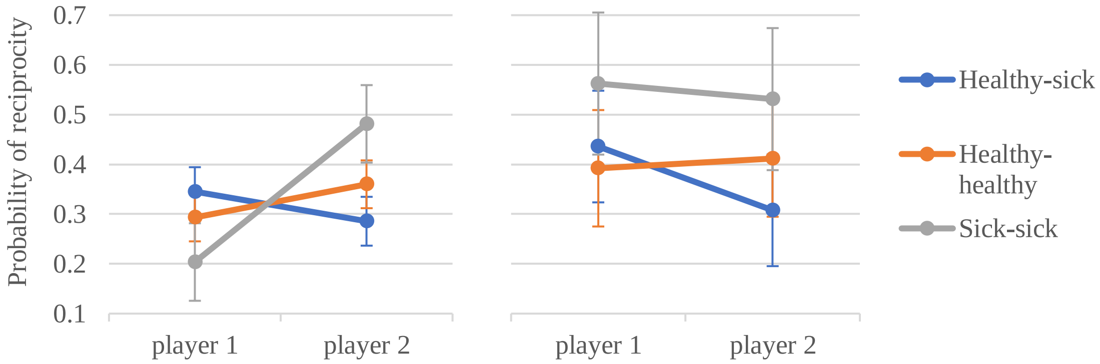


3.2.2. Partial game

Repeating the analysis conducted for the complete sample, this time with balanced group included also as a between-subjects variables, we verified that neither the main effect of receiving player nor the *Contamination group* × *Balanced group* × *Receiving player* was significant; highest F value 3-way interaction, $F(2, 111) = 2.128$, $p = .124$, $\eta^2p = .037$. However, the *Contamination group* × *Receiving player* and the *Balanced group* × *Receiving player* interactions reached significance levels, $F(2, 111) = 4.794$, $p = .010$, $\eta^2p = .080$ and $F(1, 111) = 6.235$, $p = .014$, $\eta^2p = .053$. We conducted repeated-measures ANOVAs within each group based on the balanced group and contamination group variables, including receiving player as a within-subject variable, in order to clarify these interactions (see Figure 3 for the representation of results).

For the participants who have received the ball equally from virtual players and were set on the SS condition, the main effect of receiving player was significant, $F(1, 17) = 9.444$, $p = .007$, $\eta^2p = .357$; denoting that participants chose to send the ball to player 1 more frequently than to player 2. For the remaining contamination groups, no significant effects were observed; highest F value for the main effect of receiving player on the HH group, $F(1, 24) = 2.000$, $p = .170$, $\eta^2p = .077$. Regarding the participants who have received unequal throws from virtual players, only those set on the HS contamination group revealed a significant effect, $F(1, 12) = 21.429$, $p = .001$, $\eta^2p = .641$. The remaining contamination groups did not reveal significant results; highest F value for main effect of receiving player on SS group, $F(1, 15) = 0.110$, $p = .744$, $\eta^2p = .007$.

Figure 5. Mean probability of reciprocity to player 1 and to player 2 in each contamination group and by balanced group (equal throws on left and unequal throws on right) when the game was partially completed. Error bars represent standard error of mean.



3.2.3. Summary of analysis

Similarly to the analysis reported on 3.1.1, for the participants who completed the game, the probability of reciprocity was significantly influenced by an interaction between receiving player and contamination group. Although this interaction was verified, when analyzing within each contamination group, no significant differences were observed. The interaction observed can be explained by Figure 4: participants set on the HS group reciprocated more often to player 1, when the opposite pattern occurred on groups HH and SS.

For the participants who only partially completed the game, we also observed that probability of reciprocity was significantly influenced by an interaction among the three variables (receiving player, contamination group and balanced group). Those who were set on the SS contamination condition, and received equal tosses from the virtual players, had a higher probability of reciprocity towards player 2. No significant differences were obtained on the remaining contamination groups. On the opposite, for the participants who received unequal tosses from the virtual players, those who were set on the HS condition, revealed a higher probability of reciprocity towards player 1, that is, to the healthy player than to the sick player. Once more, no significant differences were obtained on the other contamination conditions.

3.3. The impact of perceived vulnerability to disease and participants' health status on the participants' behavior

We analyzed the data collected from 53 participants who responded to the PVDS scale and to the self-report health status questionnaire. Although the sample data collected from *Cyberball* was higher than those who completed the PVDS and the self-report questions, only 53 participants completed the survey until the end.

For the analysis of PVDS, participants were divided into two groups to identify their perceived vulnerability to disease. This stratification was made through a median split from PVDS total score (*Mdn* = 4.083). As the sample size per group was too small, and more so when divided based on the PVDS values, we were unable to conduct an analysis on how perceived vulnerability affected the participants' behavior (see Table 4).

Concerning the participants' health status, they were stratified according to the grouping strategy conducted by Miller and Manner (2011): participants with an average score of 4.028 or higher (i.e., 1 SD above the mean) were considered "recently ill", and those who scored 0.776 or lower (i.e., 1 SD below the mean) were classified as "not recently ill". As the values given by the participants revealed that only 15.1% had been sick in recent weeks, we considered that it was not possible to analyze this variable, as the sample size per group was also too small (see Table 5).

Table 4.

Number of participants assigned to each condition and perceived vulnerability to disease along with mean score, median and standard error mean.

	N	*M*	*Mdn*	*SE*
Healthy-sick				
Low perceived vulnerability	6	3.361	3.583	0.242
High perceived vulnerability	12	4.701	4.708	0.130
Healthy-healthy				
Low perceived vulnerability	8	3.322	3.416	0.195
High perceived vulnerability	10	4.600	4.417	0.177
Sick-sick				
Low perceived vulnerability	10	3.433	3.458	0.161
High perceived vulnerability	7	4.595	4.500	0.140

Table 5.

Number of participants assigned to each health status along with mean score, median and standard error mean

	N	*M*	*Mdn*	*SE*
Recently ill	8	5.333	5.000	0.362
Total	53	2.402	2.000	0.223

4. Discussion

The current findings from this work contribute to the small sample of studies that have explored the behavioral component of the BEH. We hypothesized that participants set on the HS condition would tend to interact more with the player associated to the healthy descriptor and less with the player associated to the sick descriptor. For the equal descriptors contamination groups (HH and SS), we expected there were no significant differences within nor interactions between those. Although our data revealed results that are in agreement with our main hypothesis, they did not achieve significance levels: we did observe that participants on HS tended to throw the ball more often to the player 1 (healthy) than to player 2 (sick), but when analyzing the means within the group, we did not observe any significant difference. Due to the sample size limitations, we had to analyze the data from players who have completed only one part of the game. Although we observed a similar pattern in the latter case, the difference did not reach significant levels. With this, we conclude our main hypothesis that participants' when set on HS condition would throw the ball more often to the healthy player, was generally not confirmed.

The behavior of the participants from the sick-sick condition was unexpected. Although the result was significant only on the partial game-balanced condition, these participants tossed the ball significantly more often to the player associated with the descriptor of "diarrhea" as compared to that associated with the descriptor "running nose". This result partially refuses our hypothesis that the HH and SS group would not show significant differences on throws, and makes us suggest that under a situation where one must decide between two disease-related stimuli, our BEH guide us to the stimulus that likely provides less harm to our organism. In order to explore this possibility, we conducted a brief survey after this study with an independent sample, and asked participants to rate how the descriptors used on this study could be perceived as a potential source of contamination (Table 2). Ratings were provided using a scale ranging from 1 (lower perceived risk of contagion) to 7 (higher perceived risk of contagion). Participants (N=20) mean responses on the descriptors revealed the "running nose" (M = 3.35; SD = 1.09) descriptor was perceived as a higher source of contamination when compared to the "diarrhea" descriptor (M = 2.90; SD = 1.166), which could help on the explanation why we observed significant differences on SS condition. A paired-samples t-test on the evaluations of these two descriptors revealed that difference, 0.45, 95%CI [0.06; 0.96] was not statistically significant, $t(19) = 1.831$, p = .083.

We were concerned with the possibility that the participants' decision on who they would throw the ball to might be influenced by a matter of reciprocity, and not only by their descriptors. The analysis of reciprocity also showed that participants set on the HS condition, who completed the partially the game and received different number of throws from both players, tended to reciprocate more to the healthy player than to the sick player. This result was expected, as our main hypothesis assumed that participants would avoid tossing the ball to the sick player. On the other hand, participants who were set on the SS condition, partially completed the game and received the same throws from virtual players, tended to reciprocate more to player 2 ("diarrhea" descriptor) than to player 1. This last result could also be expected due to the idea proposed above about the different activation induced by these two descriptors. With these results, we can assume that reciprocity was not the main cause of participants' choice to send the ball.

There are very few studies that have analyzed the behavioral component of *Cyberball* and BEH. This investigation is a first approach that combines these two distinct procedures to analyze the behavioral strategies on BEH. But as any research, there are limitations on the present study. First, the sample size (as mentioned before): we had to make adjustments to use all the data we were able to collect from *Cyberball*. Additionally, the lack of adherence and the time frame we had to collect data was not enough to meet the minimum sample size established. Regarding the *Cyberball* itself, we observed an unequal number of throws from the virtual players to the participants, which could have been a confounding variable and, consequently, affect the data collected. Indeed, as our results revealed, such difference induced different patterns of behavior on participants. With this, future approaches that combines social interaction and BEH could explore what effects receiving additional interaction from either a healthy or a sick descriptor has on the participants' behavior. Moreover, we wanted to test the response time of participants on tossing the ball, but it was not analyzed due to software limitations: *Cyberball* timestamp of game is stored in seconds, which is not sensible enough to observe significant differences. As we were unable to test this variable, we propose it should be considered in future studies, which might provide additional information about how the behavioral component of the BEH works. We hypothesize that participants set on a healthy *vs.* sick condition, would send the ball faster if he/she received it from the sick player as compared to the healthy player. Such prediction comes from the idea that a shorter contact with the source of contamination would be more adaptive for participants. On the other hand, on conditions of identical descriptors, the response time would be similar. Furthermore, it was not possible to analyze the effect of perceived vulnerability to disease or participants health status, since the sample size of those who completed these two questionnaires was too small. We believe that a larger time frame for data collection, additional motivation for the participants' adherence to the procedure and some modifications on how *Cyberball* is programmed, would help to solve these limitations. We present them here as suggestions and concerns for future studies.

As this research was conducted in the middle of a global pandemic crisis, the behavior adopted by participants might have influence on the obtained results, as we are frequently warned about the risks of contagion and the benefits of hand hygiene. It has been reported that individuals (on this pandemic situation) are more likely to display an increase on avoidance and preventive health behaviors (Shook et al., 2020), less likely to engage in close interactions (Makhanova & Shepherd, 2020), and more likely to exhibit higher disgust sensitivity and germ aversion (Shook et al., 2020; Stevenson et al., 2021). Transposing this to our research, we could presume we would observe more interactions towards the player that shows less risk of contagion, on participants with higher germ aversion/disgust sensitivity. But as it was not possible to collect enough data sample due to limitations above (PVDS scale and the self-report health status), no assumptions can be done. Nevertheless, the tendency for the protective behavior we observed in our study, should be obtained even in non-pandemic times, as it would be the most adaptive behavior.

However, the current findings offer initial support for our procedure as a means to analyze the behavioral component of the BEH. On a more global level, they provide important information on how humans evolved to deal with disease threats, as our behavior seems to be guided to choose to interact with the stimulus that provides less or no harm. This study provides further support on BEH theory and how it works.

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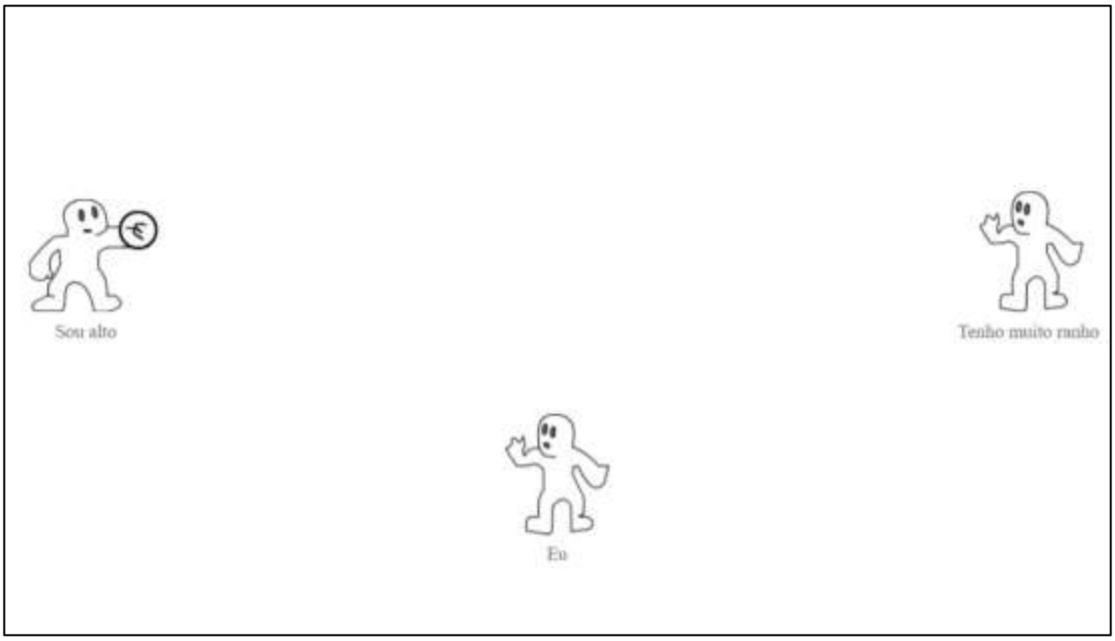
Supplementary material 1.

Screenshots of the *Cyberball* game

Figure 1. Instructions to play the Cyberball game.

It can be read in European Portuguese: “The game is very simple. When the ball is tossed at you, just click on the figure of the player you want to throw the ball to. We remind you that the main objective of the game is to MENTALLY VIEW the entire experience; it is this dimension that makes the game so important for visualization training! PLEASE DO NOT CLICK THE "NEXT" BUTTON BELOW UNTIL A MESSAGE APPEARS SAYING THE GAME HAS ENDED! If necessary, before starting this game, adjust your browser's viewing zoom so that you can see the full game window. TO START THE GAME, PRESS "PLAY".”

Figure 2. Start of the game. The player from the left starts the first toss.



Screenshots above and below refer to the HS condition. Figure on the left is the healthy virtual player, with the descriptor "I am tall" ("Sou alto"), while the figure on the right is the sick virtual player, with the descriptor "I have a running nose" ("Tenho muito ranho"). The figure from the center represents the participant. It has below a descriptor identifying himself/herself: "Me" ("eu").

Figure 3. Healthy virtual player tossing the ball to participant

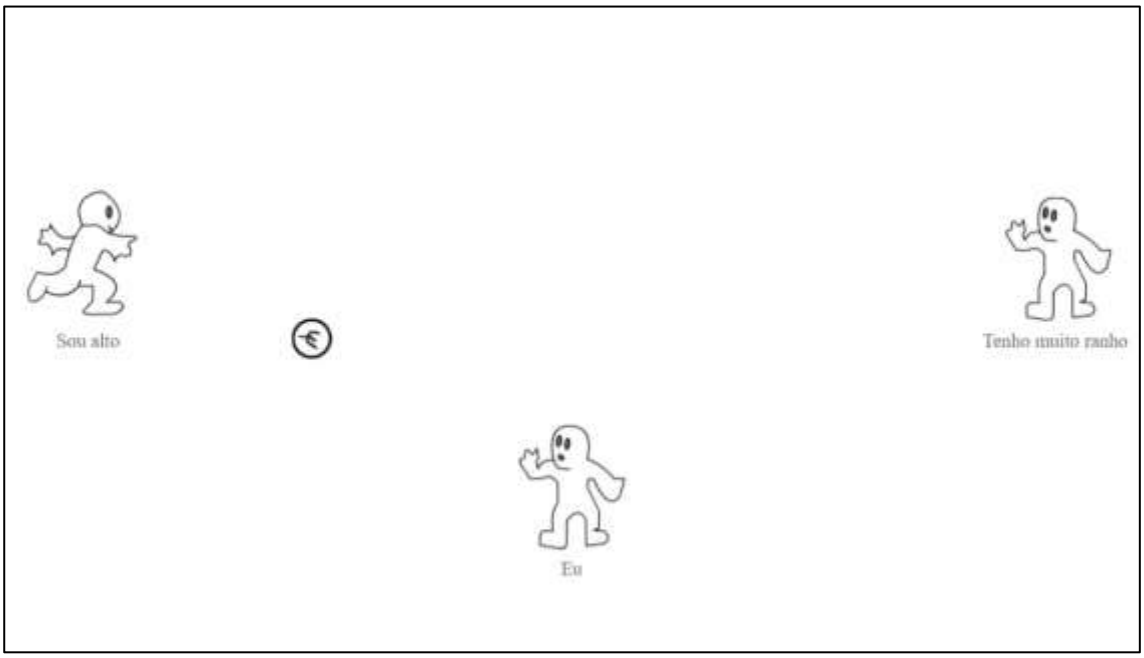


Figure 4. Participant has received the ball and no has to throw it back to wither player 1 or 2

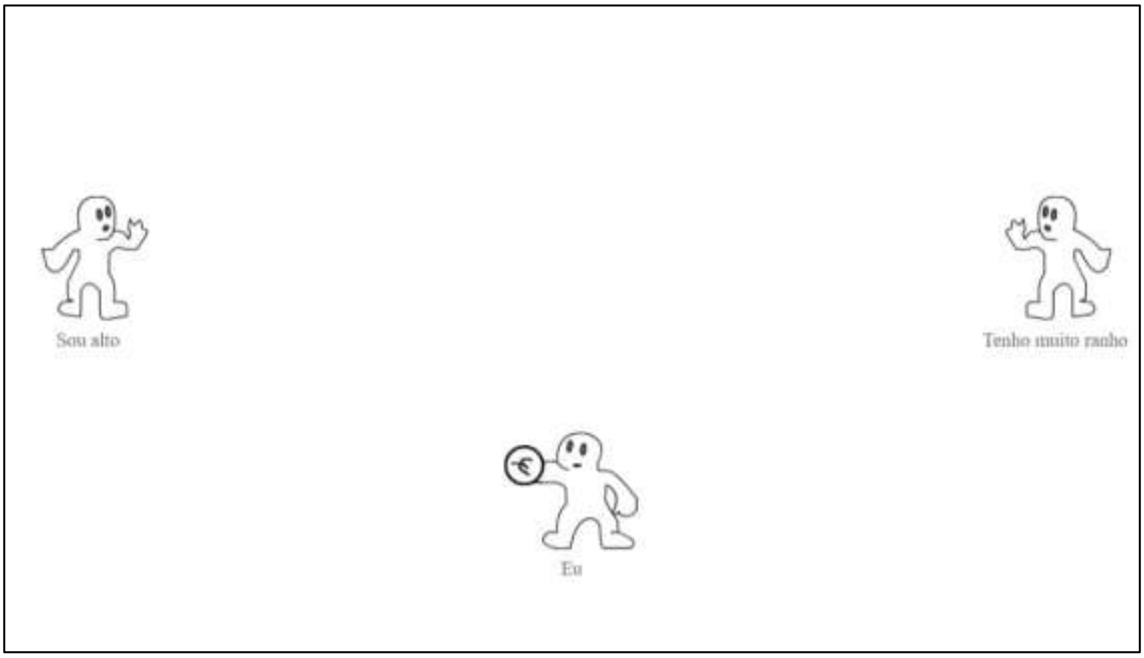


Figure 5. Participant tossing the ball to the player on the left.