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The Impact of Participants' Motivations for Engaging in Physical Activity on Their Reaction Time

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ABSTRACT

Reaction time (RT) is a measure of the time elapsed between the application of a stimulus and the subsequent response. It is considered an indirect indicator of the central nervous system's processing speed. Various factors, including body weight and physical activity, influence RT. Another factor that has not been investigated before is the effect of motivations for engaging in physical activity on motor reaction time, as measured by simple reaction time and recognition scores, indicated by the number of hits. Thus, the current study aimed to examine the impact of motivation in physical activity on RT and the number of hits. The study was conducted on 60 healthy volunteers aged 18–60 years (mean ± SD, 27.66 ± 8.31 years) who participated in regular physical activity. A headset for the virtual reality base station, controllers, and the Rezzil game were used to determine the RT. Additionally, the participants' motives for engaging in physical activity were recorded using the Leisure Motivation Scale. It was found that the RT of participants was influenced by different leisure motivation categories, particularly for males. Body mass index (BMI) also affected the RT of participants, especially in the normal and overweight groups. However, the number of hits was not influenced by such motivations. These results showed that their motivations could influence the RT of individuals who participate in physical activity. Intrinsic motivations for physical activity, like personal enjoyment, reported slower RT than extrinsic motivations like ego or competition.

Keywords: BMI, gender, motivation, physical activity, reaction time

1. INTRODUCTION

Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure (Caspersen et al., 1985). This includes a wide range of activities during leisure motivation time, from simple tasks such as walking to more intense exercises like running, swimming, etc. Individuals who engage in regular physical activity tend to have better health outcomes than those who do not. Additionally, research has demonstrated that physical activity can enhance health and reduce mortality (Haskell et al., 2007). Moreover, it is evidenced that chronic diseases such as coronary heart disease, diabetes, certain forms of cancer, and psychological problems of depression and anxiety are associated with physical inactivity or low levels of physical activity (Morris & Roychowdhury, 2020). Motivations for engaging in physical activity refer to the underlying psychological, social, or environmental factors that drive individuals to participate in bodily movement that expends energy, such as exercise, sports, or recreational activities. These motivations can be intrinsic (arising from internal desires) or extrinsic (influenced by external factors), and they vary depending on personal goals, preferences, and life circumstances (Ball et al., 2014). The task-specific motivation is narrower and focuses on performance in a given context or task. It may depend on interest in the task, its perceived difficulty, or external pressures like competition, and is usually measured by RT (Eckner et al., 2011).

Various psychological reasons are identified as causal factors for participation in physical activity; however, motivation is considered a key psychological factor leading to people's participation in physical activity and exercise (Rhodes et al., 2019). Studies on participation motivation indicate that participation motives in physical activity are linked to certain demographic variables, such as age (Egli et al., 2011), gender (Gallagher et al., 2012), culture (Walker, 2009), and preference for specific physical activity forms (Rogers et al., 2008). It is established that participation in physical activity decreases significantly with age (Caspersen et al., 2000). Studies indicate that males and females exhibit different motivations for participating in physical activity, with males showing higher motivation for challenge, status, strength, and competition. In contrast, females tend to report higher motivation for appearance, weight management, and overall health (Egli et al., 2011; Morris et al., 1995; Roychowdhury, 2012).

Motives for participation in physical activity are assessed using a validated tool called the Physical Activity and Leisure Motivation Scale (PALMS) (Zach et al., 2012). The PALMS questionnaire consists of eight sub-scales and 40 items rated on a 5-point Likert scale. In several studies (Molanorouzi et al., 2014; Morris & Roychowdhury, 2020; Roychowdhury, 2018) this scale is a comprehensive and valid measure of participation motivation in any kind of physical activity. The PALMS is an accurate tool for measuring the reasons people participate in physical activity. It comprises a 40-item measure related to physical activity and sports activity and is designed for use with adults and adolescents. Each of the eight sub-scales in the PALMS consists of five items and represents a distinct reason for engaging in physical activity. These sub-scales are mastery, enjoyment, psychological condition, physical condition, appearance, others' expectations, affiliation, and competition/ego (Zach et al., 2012).

RT is defined as the time that elapses between the presentation of a stimulus and the subsequent organism's response to it (Reigal et al., 2019). It is regarded as an acceptable measure to indicate the cognitive system to process information. It has been shown that the RT is dependent on the quickness of the sensorimotor cycle, consisting of the initial stimulus detection, transfer of the information utilising the afferent nerves, and the effector response (Greenhouse et al., 2017). The RT is particularly connected with the processing times of the central nervous system from the beginning of the stimulus to the start of muscle activity (Matić & Mrdaković, 2023).

Mainly, RT is classified into three types: simple RT, recognition RT, and cognitive RT. Simple RT is the response time to a stimulus by an observer. Recognition RT is the optimal response to several stimuli, and the response depends on the kind and form of the stimuli. Cognitive RT involves identifying a response to every type of stimulus. This type of RT consists of a process of identifying the stimuli, the relation, and the application of knowledge to obtain an optimal cognitive response in agreement with the complexity of the stimulus (Badau et al., 2018; Bari & Aldosky, 2022).

In several studies (Gajewski & Falkenstein, 2016; Gomez-Pinilla & Hillman, 2013; Mandolesi et al., 2018; Zhang et al., 2023) it is shown that brain health and cognitive performance are positively influenced by physical activity, which involves executive functions and information processing speed (Marmeleira, 2013). Individuals who are more physically active or have higher levels of fitness are more aware of their surroundings and can process information more quickly (Gomez-Pinilla & Hillman, 2013). Higher motivation levels lead to faster RT, and they are likely to encourage higher effort during testing and outcomes that more accurately reflect a subject's real abilities (Eckner et al., 2011). However, the effects of motivation in physical activity on RT have not been precisely studied. The impact of motivated self-talk on RT has been the subject of several studies. According to a study, motivating self-talk can facilitate rapid responses on choice RT tasks (Boroujeni & Shahbazi, 2011). Furthermore, Gregersen et al. (2017) showed that participants who engaged in self-talk while in an ego depletion condition had quicker RT on both the visual and auditory tests and did better on the visual test in terms of the percentage of accurate responses.

This study aimed to investigate the impact of motivation (assessed based on the PALMS questionnaire) in physical activity on RT and the number of hits for a task-specific model by using a virtual reality

(VR) headset while playing a game. This is significant because it sheds light on the relationship between brain RT and motivation for physical activity.

2. METHODS

2.1 Virtual reality device

A headset for virtual reality (HTC VIVE Headset, Republic of China), base stations, and controllers were used. The controllers and headset received signals from the base stations. Each base station had a 120° field of view. Utilising the Rezzil game (version 1.3, Rezzil Inc., Manchester, UK), the objective was to strike a virtual reality target to determine reaction time. Both hardware and software were powered by a custom-built computer (Processor: Intel® Core™ i5-4590, GPU: 1080 Ti, Memory: 16 GB, OS: Windows 10). Virtual reality operating space required a playing area of at least 2 m × 1.5 m. Audio from the software was delivered through speakers built into the headset.

2.2 Physical Activity and Leisure Motivation Scale (PALMS)

The Physical Activity and Leisure Motivation Scale (PALMS) was used to assess motivation. The PALMS is a validated instrument that has demonstrated high reliability and construct validity across diverse populations (Molanorouzi et al., 2014; Roychowdhury, 2018; Zarei et al., 2016). While the PALMS has been validated across diverse populations and languages (Kueh et al., 2017; Pérez-de et al., 2022; Santos-Labrador et al., 2021; van Lankveld et al., 2021), this study was conducted using the original English version of the PALMS questionnaire. All participants had sufficient English proficiency to understand and respond to the items without translation.

2.3 Participants

In this study, 60 participants were required to calculate the sample size with a target power of 85% (α error probability = 0.05). The sample consisted of 60 volunteers (30 males, 30 females) aged 18 to 60 years (mean ± SD; 27.66 ± 8.31 years) who participated in regular physical activity (PA) (at least 150 minutes of moderate- to vigorous- intensity PA per week) in the last three months.

Participants reported key demographic variables, including gender, age, body height, and weight. They also reported their motivations for participating in physical activity. The participants were instructed to respond to the Leisure Motivation Scale (LMS) regarding their primary motives for engaging in physical activity.

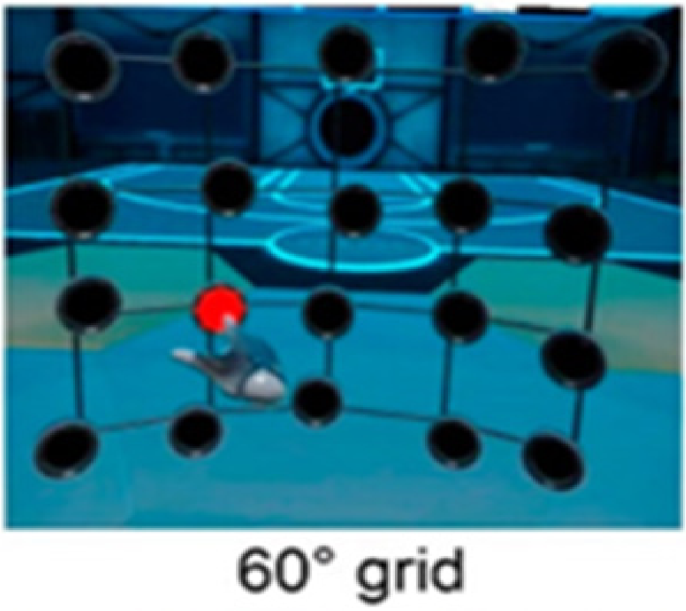
The exclusion criteria included clinical indicators of colour vision, stereopsis, strabismic disease, and ocular illness. Before the measurement, participants received an explanation of the test technique. The work was approved in writing before its commencement. The local Ethics Committee approved the study (No. 43180). The Helsinki Declaration's guiding principles were followed in the conduct of the study.

The Ethics Committee of the Physics Department (permission number: CoS.UoD/01/10/2023) approved the protocol, which enabled the study to be conducted in accordance with the Declaration of Helsinki. Each participant in the study was free to leave at any time and was under no obligation to continue the study. It was not required of study participants to explain their leave.

2.4 Experimental protocol

In this study, participants were given a Leisure Motivation Scale form, and they were instructed to select five choices from the list. Each selection corresponded to a percentage value indicating their level of association with that choice. A pre–post experimental design using the Rezzil Player, a virtual reality (VR)-based reaction wall training platform, was employed. Participants were fully immersed in VR using a 5 × 4 grid subtending 60° of visual angle (Figure 1), consisting of 20 positions. Twenty red circular buttons appeared randomly on the grid, and participants were instructed to respond as quickly and accurately as possible by touching the red-lit buttons. Once a button was pressed, it would disappear and another would light up in a new location. Each red light remained active for 200 milliseconds (stimulus ON), followed by 600 milliseconds off, resulting in a cycle length of 800 milliseconds and a frequency of 1.25 lights per second. Over the 120-second duration of each session, a total of 150 stimuli were presented. The task required participants to continuously engage with the VR interface, with stimuli appearing at random positions to train rapid visuomotor coordination. Each participant completed a 120-second pre-test session to record baseline performance, followed by a series of adaptive training trials with incremental difficulty. A 120-second post-test was then administered under identical conditions. The primary outcomes measured were average motor reaction time (ms), fastest recorded response, and number of hits.

Figure 1. **The VR training at a 60° grid**



Note: The 20 (red) circular buttons represent the target stimulus.

2.5 Statistical analysis

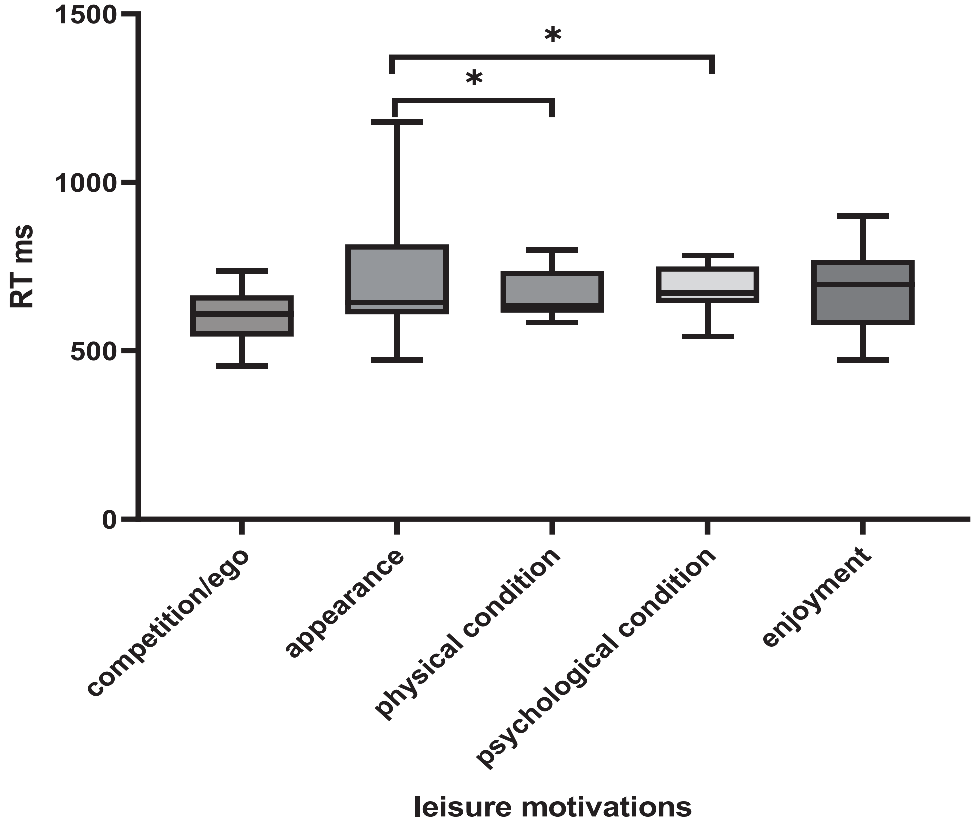
To examine the influence of leisure activity type on performance outcomes, a Multivariate Analysis of Covariance (MANCOVA) was conducted. Where appropriate, post hoc multiple pairwise comparisons employing Šidák correction were applied to explore differences between leisure activity groups. The statistical analyses were done using IBM SPSS Statistics. The level of statistical significance was set as $p < 0.05$ (exact two-tailed).

3. RESULTS

3.1 Reaction time and number of hits for different leisure motivations

Data on RT for all participants ($n = 60$) as a function of leisure motivation categories (competition/ego, appearance, physical condition, psychological condition, and enjoyment) are presented in Figure 2. The categories of affiliation, mastery, and others' expectations were excluded from the analysis due to the small sample. The appearance category had the longest RT, followed by the physical condition category, while the shortest RT was recorded in the competitive/ego category. There were significant differences ($p < 0.05$) between the appearance category and the physical and psychological conditions.

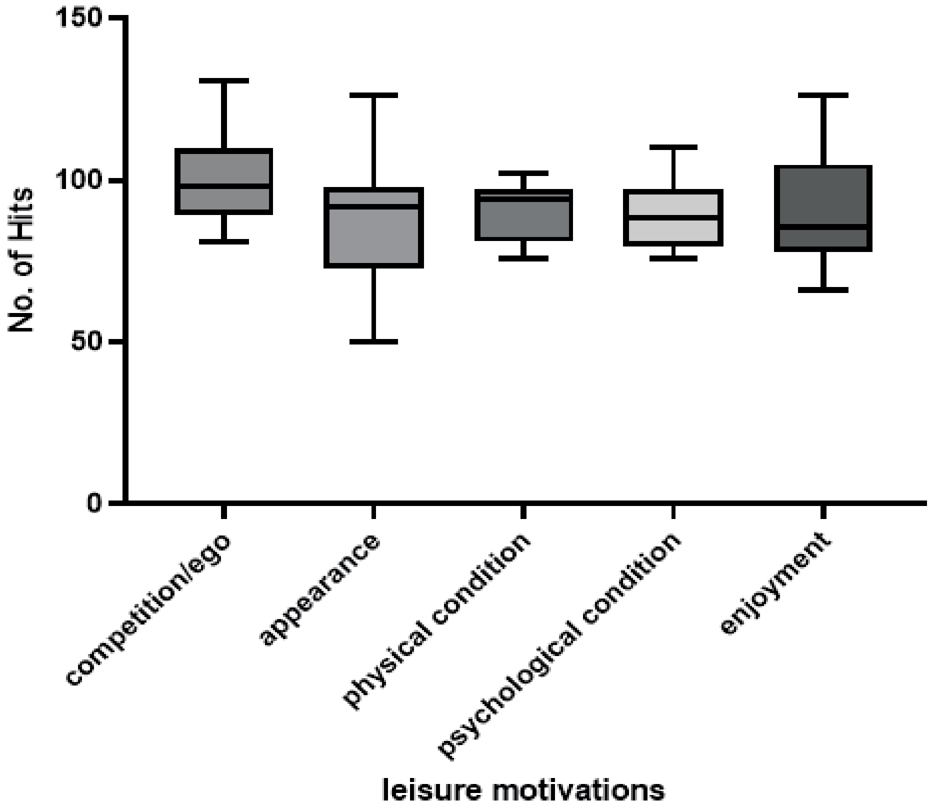
Figure 2. **RT as a function of various leisure motivations throughout all participants**



Note: * – p < 0.05.

Figure 3 displays the comparative results of the number of hits for all leisure motivation categories. The highest hit value was found in the competitive/ego category, followed by appearance. No significant differences were observed in the categories regarding the number of hits.

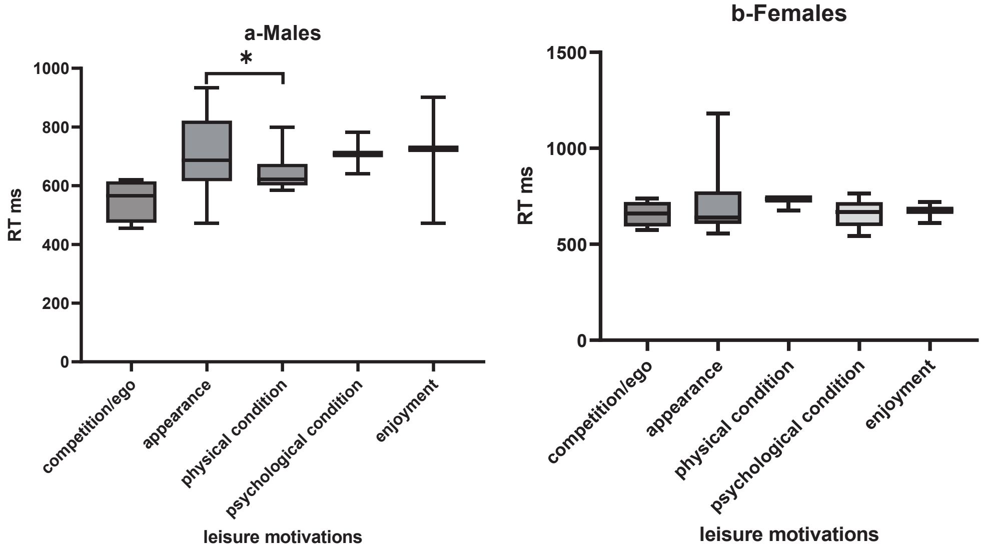
Figure 3. **Number of hits as a function of various leisure motivations throughout all participants**



3.2 RT and number of hits for the leisure motivation categories in terms of gender

There were differences in RT values between leisure motivation categories for both genders, but these differences were statistically insignificant, except for the comparison between the appearance and physical condition categories for males (p = 0.044). Males' longer reaction times fall under the enjoyment category, while females' longer reaction times fall under the physical condition category. In the competition/ego category, both genders' reaction times are the shortest, as shown in Figure 4.

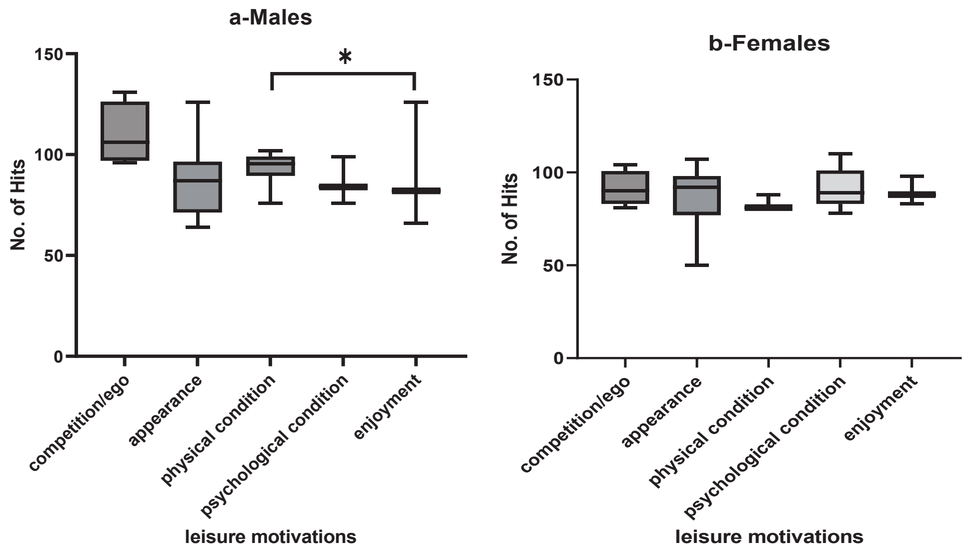
Figure 4. **RT as a function of various leisure motivations for both genders (a-Males and b-Females)**



Note: * – p < 0.05.

The number of hits for each leisure motivation category for both genders throughout all test subjects (n = 60) is displayed in Figure 5. Although it appears that there are variations in the number of hits among leisure motivation categories, particularly for men, the MANCOVA analysis revealed that these differences were statistically insignificant (p > 0.05), except for the physical condition and enjoyment category (p = 0.026) for males.

Figure 5. **Number of hits as a function of various leisure motivations for both genders (a-Males and b-Females)**



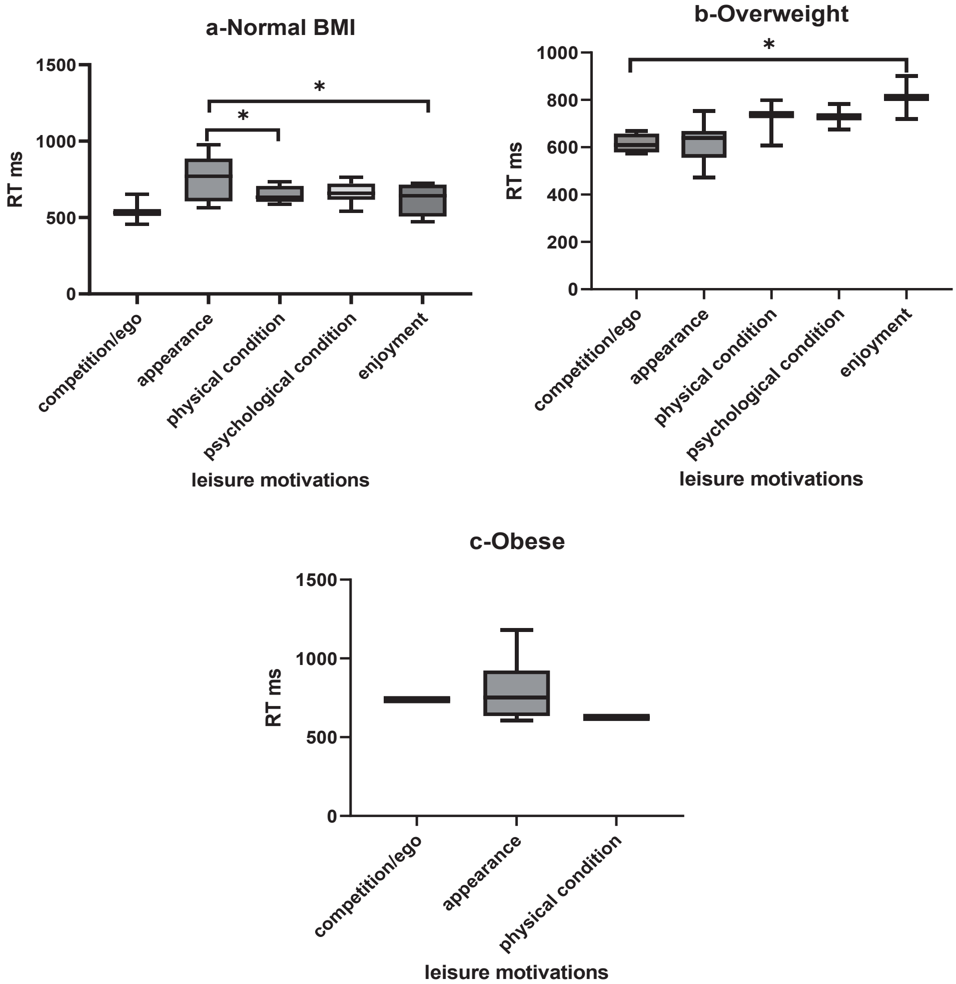
Note: * – p < 0.05.

3.3 RT and number of hits for the leisure motivation categories in terms of BMI

The results of RT for various leisure motivation categories in the three groups of participants who had different BMIs (normal, overweight, and obese) are shown in Figure 6. Significant ($p < 0.05$) differences in RT and the number of hits were seen between the two leisure motivation groups – appearance and physical condition ($p = 0.016$), and enjoyment ($p = 0.022$) – for participants with normal BMI, as shown in Figures 6 and 7. For the varied leisure motivation in overweight BMI, a linear escalating level was seen in RT, and there was a statistically significant ($p = 0.021$) difference between the competitive/ego and enjoyment categories.

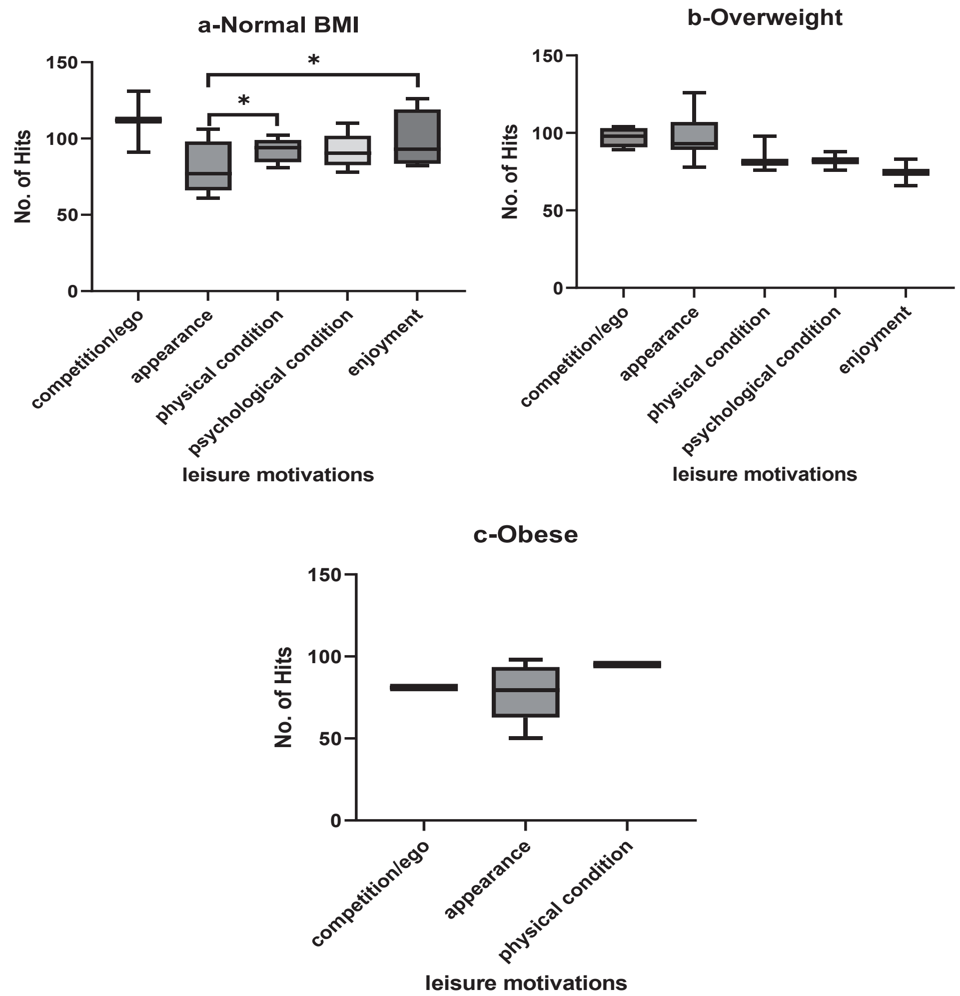
The number of hits associated with leisure motivation categories did not significantly differ for the overweight and obese groups, despite a semi-linear (Figure 7) decline in the overweight group.

Figure 6. **RT as a function of various leisure motivations for different BMI categories (a-Normal, b-Overweight, c-Obese)**



Note: * – $p < 0.05$.

Figure 7. **Number of hits as a function of various leisure motivations for different BMI categories (a-Normal, b-Overweight, c-Obese)**



Note: * – $p < 0.05$.

4. DISCUSSION

The purpose of the present study was to examine the effects of motivation for engaging in physical activity on RT and the number of hits. In the current study, comparisons were made between the RT and the number of hits of participants as a function of different leisure motivations (competition/ego, appearance, physical condition, psychological condition, and enjoyment) in physical activity, BMI, and gender. Generally, the study findings reveal that motivation in physical activity has a significant impact on the RT of individuals.

The results of this study showed that the RTs of participants were different for different leisure motivation categories. Moreover, participants who attended physical activity due to appearance as a motivation factor had the longest RT; in contrast, those who did physical activity due to competitive/ego reasons had the shortest RT. This could be due to the fact that extensive physical exercise led to a significant decrease in RT (Audiffren et al., 2008; Collardeau et al., 2001; Yagi et al., 1999). In addition, individuals who engage in physical activity for competitive/ego reasons should perform stronger exercises compared to those who do so for appearance or other leisure motivations. Moreover, during intense physical activity, the sympathetic nervous system is activated, and both blood pressure (i.e. increased blood flow) and heart rate increase. It is shown that a higher rate of blood flow allows the brain to have better cognitive functioning (Collardeau et al., 2001; Poels et al., 2008), which then should lead to faster RT since the brain reacts to stimuli faster. Furthermore, an increase in brain neurotransmitters, such as endorphins and catecholamines, following exercise could lead to an improvement in cognitive performance (Clark et al., 1989; Péronnet & Szabo, 1993). In terms of a task-specific model, the extrinsic motive is ego/competition, which tends to score faster RT. In comparison, intrinsic task-specific motivation might stem from enjoyment (slower RT). Intrinsic and extrinsic motivation are fundamentally opposed, as increased extrinsic motivation tends to diminish intrinsic motivation (Jansen in de Wal et al., 2023).

The number of hits recorded for all leisure motivation categories was insignificantly different among the different leisure motivation categories, even though they were slightly different from each other, and the highest number of hits was obtained from the participants who do physical activity due to the competitive/ego leisure motivation. This finding reveals that the leisure motivation categories do not influence the number of hits, which means that the recognition scores of participants were not impacted by different leisure motivation categories.

Findings of RT for different leisure motivation categories in terms of gender show that there were insignificant ($p > 0.05$) differences in RT values for both genders, except between male participants who do physical activity due to physical condition and appearance. This means that when the RT of participants is grouped based on gender, there is no effect of motivations for engaging in physical activity on RT, particularly in the female group. Moreover, this reveals that most differences in RT for different leisure motivations were due to differences in RT of the male group. In contrast, for females who participate in physical activity for various motivations, leisure motivation did not affect their RT. This could be because males placed a higher value on physical activity than females (Azevedo et al., 2007; Deaner et al., 2012).

With regards to the number of hits, different leisure motivation categories did not lead to different results, except between males for the physical condition and enjoyment category. Again, physical activity had no impact on the number of hits for females; this may be because females are consistently less involved in physical activity and sports in general than males. Furthermore, physical activity may lead to better motor response ability among people (males) involved in these activities (Jain et al., 2015). Also, physical activity causes higher rates of cerebral blood flow to the brain, which consequently results in improvements in cognitive functioning due to increased supply of nutrients like oxygen and glucose (Etnier et al., 1997; Jain et al., 2015; Tomporowski & Ellis, 1986).

Based on the results, BMI has a significant ($p = 0.049$) effect on the RT of the participants when they are grouped into normal, overweight, and obese categories for different motivations in physical activity. These findings are consistent with the observations of other researchers (Deore et al., 2012; Jha et al., 2021; Nene et al., 2011; Nikam & Gadkari, 2012; Skurvydas et al., 2009; Sudheer et al., 2017), who confirmed that BMI significantly impacts RT, in which participants with different BMI have different RT. Moreover, within the normal BMI group, significant differences in the RT of participants were observed, especially for appearance with each physical condition and enjoyment. Significant effects between the RT of competitive/ego with enjoyment category in the overweight group were found. Concerning the obese group, due to the low sample size of participants and the absence of participants for some leisure motivation categories, the effects of physical activity on RT of this group were not found in this study. However, it is reported that individuals with greater BMI reacted significantly slower than others (Skurvydas et al., 2009). This could be due to BMI's affect on sensory-motor association (Nene et al., 2011). Also, overweight and obesity cause several medical conditions, which consequently influence cognitive function, attention, and memory (Deore et al., 2012; Jha et al., 2021). Gunstad et al. (2006) showed that the elevated BMI values reduce cognitive performance, which slows the processing capability and leads to longer RT (Sudheer et al., 2017). Other hypotheses are associated with the underlying mechanisms of the adipose tissue secretions, such as cytokines, hormones, and growth factors, which could cross the blood-brain barrier, as a result influencing brain health (Deore et al., 2012).

The three groups also showed different numbers of hits when they grouped based on BMI, in which leisure motivation categories had a significant effect on the number of hits in the normal group, whereas the number of hits did not significantly differ between the obese and overweight groups.

Limitations

This study presents significant contributions, including its novel focus on the relationship between motivation for physical activity and reaction time (RT), a topic that has received limited attention in previous research. By incorporating both psychological (motivation categories) and physiological (RT performance) dimensions, it offers an interdisciplinary perspective that enhances our understanding of cognitive-motor processes. The use of a VR-based assessment method further adds methodological innovation and ecological validity, while the inclusion of gender and BMI as additional variables enriches the analysis and provides practical insights for tailored interventions. Despite these contributions, the study is not without limitations.

The relatively small and homogeneous sample size limits the generalisability of the findings across broader populations, and the cross-sectional design precludes causal inference. Motivation data were self-reported, which may introduce response bias, and several potential confounding factors – such as fatigue, sleep quality, and prior gaming experience – were not controlled. Moreover, the statistical power for subgroup analyses, particularly in the obese category, was low, reducing the robustness of certain comparisons. Furthermore, while VR technology offers advantages, its ecological validity for real-world cognitive-motor performance remains uncertain. Future research should employ larger, more diverse samples, consider longitudinal designs, and include additional control variables to strengthen the validity of these findings. Finally, although the PALMS questionnaire was administered in English to participants with adequate language proficiency, it has not yet been formally validated in this specific cultural context. Future research should consider conducting local psychometric validation to further strengthen its applicability in similar populations.

5. CONCLUSIONS

In conclusion, the effects of motivation in physical activity on task-specific RT and the number of hits were investigated among individuals who attended physical activity for different leisure motivations. Different leisure motivations influenced the RT of male participants, but such effects were not seen among females. BMI has a significant influence on RT, even among normal individuals. The extrinsic motivations, which are influenced by external rewards, such as ego/competition, recorded faster RT than intrinsic motivations for engaging in physical activity, which are driven by internal rewards, such as personal enjoyment. The number of hits was not impacted by different leisure motivations, which was more robust in this context. Different motivations for engaging in physical activity may impact RT and the cognitive performance of participants in this task; however, more research is needed to examine the effects of different exercises and tasks to examine the specific effects of RT with both simple and choice RT.

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