Do user motivation and attention influence performance of a postural reaching task in a virtual environment?

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ABSTRACT

Practice in a virtual environment (VE) can enhance motivation and attention, but the relationship between these constructs and motor skill acquisition requires exploration. This study evaluated the impact of motivation (as measured by the Intrinsic Motivation Inventory) and attention to a task-irrelevant visual distraction (as measured by proxy via recall) on performance of a postural reaching task in a 2D VE in 27 young adults. Higher motivation was associated with higher scores, while poorer attention to task was associated with lower scores. Findings suggest that motivation and attention can impact VE practice; subsequent research will include retention and transfer tests.

1. INTRODUCTION

Virtual environments (VE) are increasingly common rehabilitation tools, yet much remains to be understood about how practice in a VE might enhance motor skill performance and learning as compared to practice in a physical environment. Motor learning is influenced by practice conditions during skill acquisition (Schmidt & Lee, 2011). Practice in a VE differs from the physical environment in ways that may facilitate motor skill acquisition and learning (Levac and Sveistrup, 2014). In particular, clients report high levels of motivation to practice in VEs (e.g., Tatla et al., 2013). While this enhanced motivation may indirectly enhance practice *quantity*, the extent to which motivation can directly affect motor learning processes to enhance practice *quality* is of particular interest (Lohse et al., 2016). Enhanced motivation is a prevalent rationale for VE use (Levac and Sveistrup, 2014), but few studies have explored the effects of motivation on motor skill performance and learning in VEs. Most recently, Lohse et al. (2016) found no relationship between motivation during practice of a new motor skill in a VE by healthy young adults and performance, retention or transfer of that skill.

VEs may support practice quality by enhancing engagement (Lohse et al., 2016). Engagement is defined as “an affective quality or experience of a participant in a task that emerges from focused attention, aesthetic pleasures, and perceptions of novelty” (Leiker et al., 2016, p. 4). Attentional resources and attentional demand may be feasible methods to objectively measure user engagement in VEs. Attentional reserve, as measured physiologically by EEG magnitude of event-related potentials (EVPs) to task-irrelevant probe tones, has been linked to self-reported engagement in a VE motor learning task (Leiker et al., 2016). The attentional demands of practice in a VE (as measured using verbal response time to an auditory tone) are higher than in the real world (Chen et al, 2015). Many tasks in VEs require dynamic movement, rendering EEG measurement of EVPs more challenging due to substantial artefact. VEs in which auditory elements are essential components complicate measuring responses to task-irrelevant auditory probes. As such, evaluating attention to task via a distracting visual stimulus could be a low-cost engagement proxy. Understanding whether attention to task relates to performance outcomes provides a rationale for further exploration of this type of measure.

The purpose of this study was to evaluate the impact of motivation and visual attention to task (as measured by recall of the contents of a distracting stimulus) on performance of a postural reaching task in a VE. The postural reaching task was practiced under ‘easy’ or ‘hard’ task parameter conditions. We hypothesized that 1) participants in the difficult practice condition would be more motivated and recall less of the contents of a distracting stimulus as compared to participants in the easy practice condition; 2) motivation would inversely correlate with recall; and 3) higher motivation and poorer recall (i.e., more attention to task) would be associated with better performance in both practice conditions.

2. METHODS

This cross-sectional study involved a convenience sample of healthy young university students without motor or cognitive impairments. The study took place in Northeastern University's Rehabilitation Games and Virtual Reality (ReGame-VR) laboratory using the Stability and Balance Learning Environment (STABLE; Motek Medical, The Netherlands), a virtual environment incorporating a force plate and motion capture cameras.

2.1 Procedures and task

Participants stood on a force plate holding a lightweight wand with a retroreflective marker in their dominant hand. Following calibration of reach distance and limits of stability, participants received standardized instructions to move their body, but not their feet, to 'unlock' a target (a circle covered by a gate) in the VE displayed on the screen in front of them and then 'touch' the target with their wand as quickly as possible. Successful touch required that the target be 'unlocked' (i.e., make the gate rise) by sufficient center of pressure (COP) displacement. COP displacement progress (i.e., gate movement) was indicated on the screen. Each trial involved a random sequence of 6 targets. Participants were randomly assigned to either the 'easy' or 'hard' practice condition, differentiated by time available per target and amount of COP displacement required. Participants practiced 100 trials of the task. Visual and auditory knowledge of results feedback was presented about success or failure of touch per target, and numeric knowledge of results feedback was presented per trial (trial score and cumulative score). Ambient task-related sound played in the background. A task-irrelevant visual stimulus (a soundless nature video) played on a monitor in the participants' left peripheral vision; the monitor was positioned such that participants could always see it in their peripheral vision but would need to actively turn their heads away from the VE in order to view the contents of the video.

2.2 Outcome measures

1. *Trial score.* Average time to successful 'unlocking' (via COP displacement) and touch for the 6 targets in a trial. Total score reflected cumulative trial score across 100 trials.
2. *Intrinsic Motivation Inventory (IMI):* The IMI is a 15-item questionnaire assessing participants' interest/enjoyment, perceived competence, effort, value/usefulness, and pressure/tension in completing a task. Questions were modified to be specific to the task.
3. *Recall of contents of a task-irrelevant video stimulus:* A study-specific questionnaire asked participants to recall the content of a soundless nature video that played in their peripheral vision during task practice. Participants identified the animals and scenes that made up the video; 1 point was given for each correct answer. We anticipated that participants who paid more attention to the video would be more likely to recall its contents.
4. *Self-report frequency of video gaze shifts:* We asked participants to rate the frequency with which they looked at the video using a 7-point Likert scale.

2.3 Analyses

Independent-t tests were undertaken for between group differences in each outcome measure. Pearson correlation evaluated the relationship between IMI and recall. Mixed non-linear regression models explored changes in score across trials. These models account for within-subject correlation and separate within-subject and between-subject variation of repeated trials on individual participants. IMI and recall scores were covariates in the mixed model to assess their relationship with practice condition and performance score.

3. RESULTS

Twenty-seven healthy young adults (10 males, 17 females) participated (14 in the 'easy' condition and 13 in the 'hard' condition). Participants had a mean age of 22.1 years (SD 2.1) years. There was a significant difference (mean difference [MD] = 3.5, standard error [SE] = 1.23, t = 2.845, p = 0.005) in mean trial scores between the 'easy' and 'hard' groups. The 'easy' group had an average higher score of 3.5 points over the 100 trials. There was a significant difference in total score between groups (MD = 277.6 pts, SE 50.2 pts, t = 5.524, p = .001) with the 'easy' group having a higher score. Figure 1 illustrates performance scores for all participants.

Average IMI score for all participants was 50.1% (SD 11.1%). There was no significant difference (MD = 8.27839, SE = 4.11247, t = 2.013, p = 0.055) between 'easy' (54.9 [SD 11.4]) and 'hard' (46.7 [SD 9.5]) group IMI scores. The mixed model analysis revealed a significant positive association between IMI scores and trial scores (t= 7.01, p = 0.001). For every 1% increase on the IMI, mean trial scores increased by 0.55 points. This association was significantly modified by group (t = -5.869, p = 0.001) with participants in the 'fast' condition demonstrating greater increase in mean trial score with increased motivation. Average recall score (on a 0-100 scale) for all participants was 33.7% (SD 21.7%). There was no significant differences between groups in recall scores (Easy mean: 32.7 [SD] 20.9), Hard mean: 32.9 [SD]: 23.2). However, there was a significant main effect of recall on skill acquisition. With every increase of 1 point in recall score (reflecting better recall of video contents), the mean trial score decreased by .2 points (t = -6.56, p = 0.001). There was no group interaction in this relationship. A significant main effect was observed such that as participants reported looking more frequently at the video, mean trial score decreased 2.02 points (t= -3.31, p = 0.003). Finally, there was no correlation between IMI scores and recall (r = .173, p = 0.409).

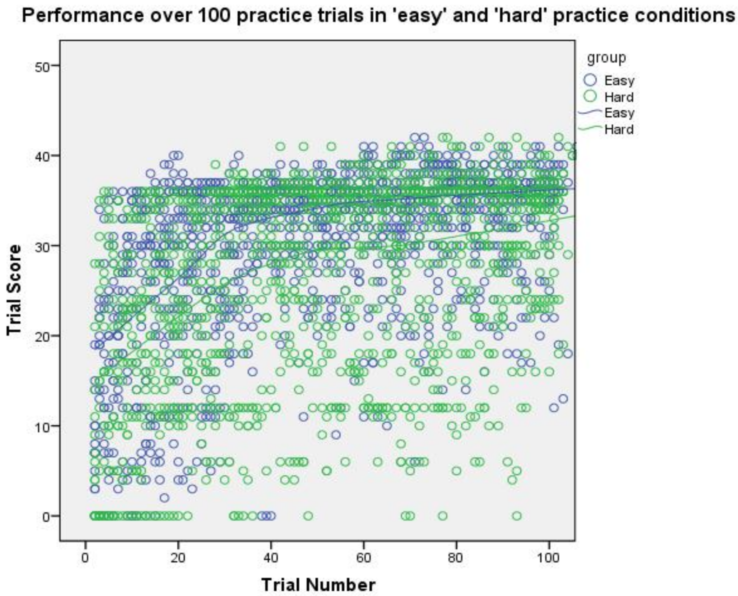

Figure 1. *Performance scores over 100 practice trials.*

4. DISCUSSION

This study explored the impact of user-reported motivation and recall of the contents of a distracting visual stimulus (as a proxy for attention to task) on performance of a postural reaching task in a VE in healthy young adults practicing under two challenge conditions. As this was the first evaluation of the task, the differing challenge conditions were utilized to inform task parameter selection for subsequent research purposes. As would be expected, participants in the easier practice condition performed better (as evidenced by higher scores). However, Figure 1 illustrates that neither practice condition posed significant difficulty for our participants. Although some between-person variability is evident, most participants had reached a maximum skill level following approximately 30-50 practice trials. This suggests the need for greater task precision to enable incremental increases in performance skill over time.

Despite differences in acquisition performance, we did not see hypothesized between-group differences in motivation or recall scores. We had expected that participants who practiced in the more challenging condition would report higher motivation to succeed and demonstrate less recall of the secondary video content (i.e., greater attention to the task) than would their counterparts in the easier condition. However, we did not elicit sufficient challenge during practice even in the more difficult condition nor did participants find the task highly motivating (overall mean IMI 50.1%, SD 11.1%). Despite evidence of a relationship between recall of the contents of a distracting video and task performance, participants overall could recall little about the distracting video (mean attention score 33.7%, SD 21.7%). Findings related to our attention proxy are clearly limited by the nature of this measurement, as recall challenges cognitive functions unrelated to attention. Some validation for the recall measure as a proxy for attention is evidenced by the fact that participants who self-reported looking more frequently at the video had poorer performance on the task. A further limitation is that the recall measure was time-related; given that we saw participants' performance plateau about midway through the testing session, it would have been valuable to more specifically capture whether attention to the video was more pronounced in the latter versus the earlier half of the practice session. Furthermore, we did not screen participants for an attention deficit disorder that may have impacted their attention to any task in any setting nor did we evaluate their memory recall capacities. Subsequent research will utilize more objective ways to measure attention to a distracting peripheral stimulus, including facial tracking to quantify screen views.

Despite these measurement issues and as hypothesized, motivation and recall (as a proxy for attention) were associated with skill acquisition. The effect for motivation was moderated by practice challenge, with participants in the hard condition increasing performance scores with greater motivation to a greater extent than participants in the easy condition. There was no effect of practice condition for the relationship between recall and skill acquisition. To our knowledge, this is the first study to demonstrate these effects for acquisition phases of learning a motor task in a VE. Lohse et al. (2016) did not find a relationship between self-reported IMI score and acquisition or retention of a motor task in a VE. Leiker et al. (2016) showed that attentional resources (as measured by EVPs on EEG) correlated with self-reported engagement, but no relationship with performance or learning was seen. The neurophysiological mechanisms by which motivation and attention might enhance the quality of motor learning of a new task are outlined by Wulf and Lewthwaite (2016) and include responses to positive experiences and strengthening of functional neural connections. Further exploration of valid measures of motivation, attention and engagement as potential '*active ingredients'* of practice in a VE that might enhance learning outcomes is important to provide evidence informing therapist decision-making about using VEs as compared to conventional real-world practice.

Our study is further limited by the fact that we did not measure subjective user engagement. Doing so would have supported exploration of the relationship between self-reported recall of a distracting stimulus (as an attention proxy) and engagement and provided more evidence to support or refute perusal of other measures of attention for their potential links to engagement in future studies.

5. CONCLUSIONS

Task challenge, motivation and recall of the contents of a distracting visual stimulus all related to performance of a postural reaching task in a VE. Although limited to motor skill acquisition rather than learning, this study adds to the growing body of literature about the significance of the user's affective state in VE practice settings. Future research will objectively evaluate visual attention, measure subjective engagement and evaluate the impact of these constructs on motor learning through delayed retention and transfer tests.

6. REFERENCES

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