Influence of Movement Expertise on a Virtual Point-to-Origin Task

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ABSTRACT

There is increasing evidence of individual differences in spatial cognitive abilities and strategies, especially for simulated locomotion such as virtual realities. For example, Klatzky and colleagues observed two distinct response patterns in a "point-to-origin" task where participants pointed back to the origin of locomotion after a simulated 2-segment excursion. "Turners" responded as if succeeding to update their heading, whereas "non-turners" responded as if failing to update their heading - but why? Here, we investigated if one's real-world movement and movement analysis expertise (i.e., dancers versus Laban Movement Analysts) might affect one's virtual orientation behaviour. Using a virtual point-to-origin task, data showed that participants (N=39) with more extensive movement analysis expertise tended to be turners, and thus incorporate visually presented turns correctly. Conversely, dance students without Laban Movement Analysis expertise tended to be non-turners or used a mixed strategy. This suggests that reflecting about self-motion might be more conducive than movement experience, primarily dance, alone for enabling correct updating of simulated heading changes.

Author Keywords

Spatial cognition, spatial orientation, navigation, movement expertise, virtual environments, point-to-origin, Turner, Non-turner

ACM Classification Keywords

H.1.2 [Models and Principles]: User/Machine Systems—Human factors H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities H.5.2 [Information Interfaces and Presentation]: User Interfaces—Input devices and strategies J.4 [Social and Behavioral Sciences]: Psychology

INTRODUCTION

We are able to navigate and orient ourselves effortlessly through the world. Yet, when we put ourselves in a virtual world navigation becomes cognitively more demanding. Why the discrepancy? Normally we rely on vision, audition, vestibular, and proprioceptive input to automatically guide us and update our position [13]. And, there are two distinct reference frames we use: egocentric, self-to-object representation, and allocentric, object-to-object representation. While we primarily use our egocentric reference to navigate in the real world, when we imagine the same path we tend to use a mixed strategy to determine where we are. In our experiment, participants saw simulated self-motions through four virtual starfield paths and were then asked to indicate on their response sheet where the origin was as if they had actually travelled along that virtual path, similar to [2]. We used a classroom setting in order to investigate how the findings from lab studies [16,17] and online studies [4] relate and generalize to a group setting that allows for parallel presentation and response recording.

Researchers [5,10,14] have discussed a phenomenon connecting spatial updating and spatial representations. When making a pointing response one can potentially commit 2 types of errors: hemispheric (left-right) and anterior-posterior (front-back), which elicits 4 categories of responses. These 4 response categories could suggest the use of different navigation strategies and potential underlying spatial representations (cf. **Fig. 1**). So-called "**Turners**" point to the correct hemisphere, i.e., respond as if they successfully updated their heading, which could be associated with self-to-object, egocentric, or 1st person perspective. "**Non-turners**" point to the incorrect hemisphere, i.e., respond as if they failed to update their heading, which might be associated with object-to-object, allocentric, or 3rd person perspective. "**Non-movers**" respond as if they not only failed to update the heading but also the movement itself, and pointed from the origin to the end location, therefore committing an anterior-posterior error. "**Spinners**" responded as if they arrived at the end point, turned 180° to face the path, and then pointed to the origin from the new orientation, therefor committing both hemispheric and anterior-posterior errors. The introduced navigation strategies could explain the variety of pointing response patterns [4,5], however they do not serve as a definitive model of actual cognitive processes involved.

MOCO '15, August 14 - 15, 2015, Vancouver, BC, Canada

DOI: http://dx.doi.org/10.1145/2790994.2791014

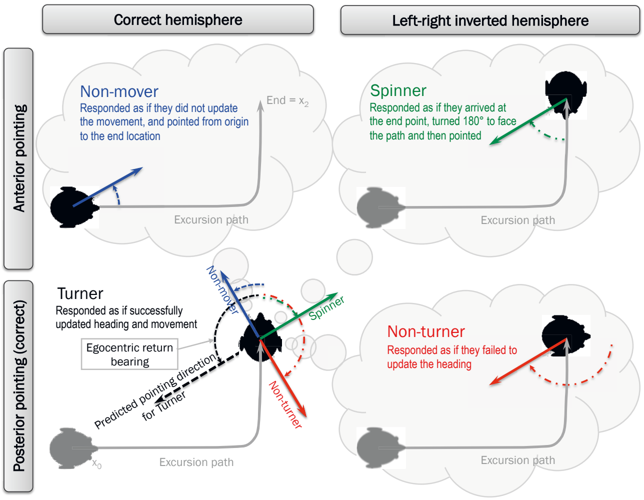

Figure 1 Trajectories and predicted responses for turners (bottom-left), non-turners (bottom-right), spinners (top-right), and non-movers (top-left) from a birds-eye-perspective. Excursion path is the first-person perspective movement along that trajectory.

Previous studies have looked at the individual factors that may influence the strategy used for spatial updating in a virtual point-to-origin task, such as gender, video gaming experience, ethnicity, response mode, navigation skills, cardinal direction proficiency, and decision certainty [2,4,14,18].

Here, we investigated if and how participants' real world movement versus movement analysis expertise might influence virtual navigation strategy. Spatial awareness and body representation are two main cognitive abilities in which dancers are trained [8]. Body awareness [12] and accuracy of proprioception [9] are shown to be better in expert dancers than novices.

In egocentric spatial movement and body orientation, the posterior parietal cortex is thought to give body awareness for spatial positioning. This is important for dancers' bodily control and orientation; navigating space during leaps and turns requires sharp spatial awareness [1]. However, the unique self-motion abilities in professional gymnasts is linked to superior interpretation of otolith signals (linear leftward-rightward motions) when no change in canal signals (yaw, pitch and roll rotations) is present [6].

It appears that different movement expertise is associated with different types of spatial awareness. However, in the virtual world, the link between movement expertise and spatial orientation is largely unexplored. Are movement experts more likely to update their movement and heading correctly in order to navigate a virtual space? That is, our goal is to determine if there is an association between movement experience versus movement analysis expertise and strategy preference.

METHOD

Participants

To compare with our general population sample from a previous study [8], the same virtual point-to-origin task was used to collect data from a purposive sample of 39 participants (26 females) with an age ranging from 19 to 59 years old (Mean=32): 15 first-year dancers at the School for Contemporary Arts at Simon Fraser University (SFU) and 24 participants at Emily Carr University, of which 8 were classified as movement experts. Although first year dance students, these dancers already had an extensive background and experience in dance. The experts at Emily Carr in our sample had greater than 5 years experience in dance and were movement analysis trained in Laban Movement Analysis, which has rich epistemological history particularly in the domains of dance, non-verbal communication, psychoanalysis and psychology providing rigorous explanatory models for the description of movement [3,11].

Stimulus and Apparatus

Participants were shown a passage through a virtual starfield, providing optical flow without any landmarks. The stimulus was presented on a projector and lights were dimmed. Participants were asked to group as closely as possible around the projector to minimize extreme viewing angles. Trajectories consisted of an initial straight path, followed by a curve and a second straight path at the end. Curve angles used for the four trials were 60° left, 90° right, 90° right and 60° left. Answer sheets consisted of a multiple-choice paper questionnaire. For each trial of the point-to-origin task, participants were given 4 possible answers to select from: front left, front right, back left, and back right for both the textual condition and the pictorial condition. For each trial, the order of response choices was randomized to avoid answering tendencies. The response form was folded and sealed with tape, with the demographic information questionnaire inside to prevent possible task performance bias.

Procedure

The experiment took place at the School for Contemporary Arts SFU (N=15) and Emily Carr University of Art and Design (N=24). All students volunteering to participate signed the consent form and were randomly handed a pictorial or text condition response form. The experimenter then explained the task until no participant had further questions. Participants were asked to select the answers as quickly and intuitively as possible. They were instructed not to copy from their neighbours or discuss their answers until after the experiment. After dimming the lights, 4 trials were presented on the projector screen, pausing after each trial allowing everyone to make the response. No questions regarding correct responses were answered. After completing the task, the room was illuminated again and participants were asked to open their forms and fill out the demographics questionnaire. In total, the experiment took approximately 10 minutes.

Data Collection and Analysis

For each trial, the response was identified as indicating one of 4 strategies: turner, non-turner, non-mover or spinner. In accordance with previous studies (e.g., [4]) participants were classified as users of the respective strategy when they provided responses with a specific strategy in at least 75% of the trials, otherwise they were classified as having “no preference”. Response mode, pictorial and textual, was not analyzed due to time constraints.

To test if there was an association between the frequencies of spatial orientation strategy preference (i.e., turner, non-turner, and no preference) and the frequencies of different types of movement experience (i.e., <5 years dance, 1st year dance students, and >5 years dance), we performed a two-tailed Fisher’s exact test. A chi-square test was not applicable because the condition of all expected frequencies to be greater than 5 was not met.

RESULTS

The analyses of the full sample across all movement expertise levels reveal the following spatial orientation strategy preferences: 28.2% of participants were turners (<5 years: N=5; >5 years: N=6), 33.3% were non-turners (1st year: N=7; <5 years: N=6), and 38.5% had no preference (1st year: N=8; <5 years: N=5; >5 years: N=2). No consistent spinners or non-movers were observed in the data, however these strategies were suggested by individual responses. When analyzing at each level of movement experience we observed (cf. **Fig. 2**): 1st year dance students were 46.67% non-turners and 53.33% no preference; <5 years movement experience were 31.25% turners, 37.5% non-turners, and 31.25% no preference; >5 years movement experience were 75% turners and 25% no preference.

The two-tailed Fisher`s exact test yielded a significant association between the type of strategy preference and the level of movement experience $\chi^2(N=39) = 15.61$, $p = .002$, Cramer’s V = .446. This represents a medium association between type of strategy and level of movement experience. When movement experience was >5 years the standard residual was significant for the turner strategy preference ($z = 2.5$). For 1st year dance students, the standard residual was also significant for turner strategy preference ($z = -2.1$).

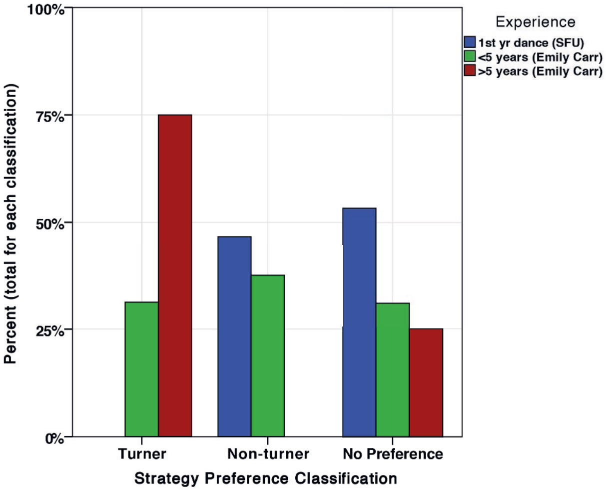

Figure 2. Percent (total for each experience level) of preferred strategy classifications based on movement experience.

In other words, when movement experience was >5 years significantly more participants were classified as turners, than would have been expected if there were no affect of movement expertise. For 1st year dance students, significantly less participants than expected were turners. All other associations were non-significant.

DISCUSSION

Consistent with our prediction, spatial orientation strategy preference in a virtual environment is associated with movement experience. The standard residuals suggest that the association between the level of movement experience and strategy type is evident primarily when movement experiences are >5 years or 1st year dance students. In other words, participants with >5 years of movement experience and movement analysis training were likely turners whereas 1st year dance students were likely not to be turners. Results suggest that increased movement analysis and movement experience, predominantly dance, is more closely related to the ability to incorporate visually presented turns and update heading correctly in order to navigate a virtual passage.

One possible explanation for the association between dance experience and orientation strategy preference is that Laban Movement Anaylsts have to constantly think about their own bodies in relation to different perspectives, and that

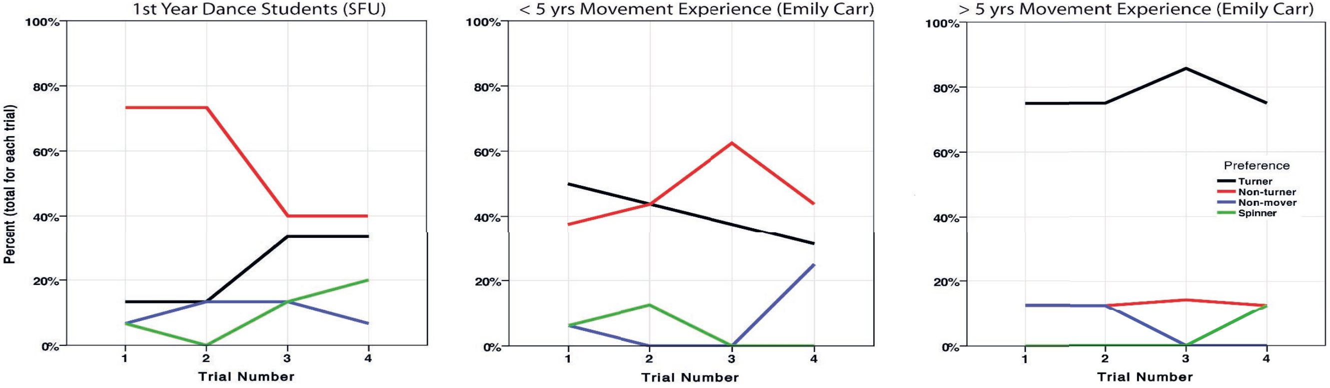

Figure 3. Percent of strategy preference over each trial for 1st year dance students (left), <5 years movement experience (center), and >5 years movement experience (right).

experience improves their ability to update their heading in other scenarios, like virtual environments. In contrast, those with little or no movement analysis expertise still do not have that experience ingrained in them yet, and so do not update their heading correctly. This hypothesis is consistent with our data (cf. **Fig. 3**). Overall, it appears those with established movement expertise are consistently updating their heading correctly, while those with less established movement expertise produce inconsistent responses in virtual navigation tasks.

There are several limitations in this study: the experiment took place at different locations, SFU and Emily Carr, so there may be some effect of location even though we kept the set up (classroom style around a projection screen) as consistent as possible. Another limitation is that we cannot be sure that participants completely understood the task, even though we replicated the instructions from [2] and only started the experiment after participants claimed to understand the instructions. Finally, our study analyzes only dance as a form of movement expertise. Other movement experience forms, such as yoga, may reveal different trends in strategy preference.

The next step is to examine different types of movement expertise for a larger participant sample. Examining different dance culture types, as well, may yield differences in strategy preference because dance in some cultures takes an egocentric perspective while others are allocentric [7]. Additionally, active control of locomotion may yield different results. [15] compared active and passive locomotion in a virtual environment and found user-initiated motion cueing can provide a means of increasing self-motion. Finally, we are currently expanding this classroom experiment to an online version in order to gain a greater number and spread of participants.

CONCLUSION

Our study seems to suggest that movement and movement analysis expertise is linked with spatial updating performance in virtual environments. However, it is still unclear if performance is only due to movement analysis expertise or if it is related to some other underlying factor common in movement experts. Virtual environment designers should take individual differences, such as movement expertise and different reference frame proclivities, into account when creating a virtual travel experience because users individual differences can affect their behaviour and underlying mental spatial representations.

ACKNOWLEDGMENTS

Support: SSHRC. Thanks to Thecla Schiphorst and participants who offered their time and expertise.

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