THE INFLUENCE OF SPATIAL WORKING MEMORY ON MOBILE LEARNING CONTENT DESIGN

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ABSTRACT

Whilst there are relatively well-established guidelines for desktop-based learning systems, new forms of learning activities with small handheld devices have yet to be firmly standardized. In light of this, there is a strong case for re-visiting some basic principles for mobile learning systems design, such as how to deliver learning content when a key assumption is that this should be tailored to individual differences. Two approaches to mobile learning content design are considered in this article, one using plain-text and the other using media-rich content such as visual animations and aural narrative. An experiment is described which shows that some learners are sensitive in preference to the multimedia-based mobile learning system and these results are interpreted by means of spatial working memory capability. Guidelines for designing mobile learning content are suggested that might help to indicate the effectiveness of mobile learning systems in relation to differences in individual spatial memory.

KEYWORDS

Spatial working memory, mental rotation test

1. INTRODUCTION

Whilst there are multiple factors that the successful mobile application shares with desktop-based applications, it cannot simply be a desktop application ported to the mobile environment. It is quite clear that a well-designed mobile application, to be successful, cannot be just a subset of the corresponding desktop application, but rather will partially overlap and complement the corresponding desktop application's features.

Unlike the substantial advances in mobile hardware over the last decade, the context of use of the mobile phone has not significantly changed, so very few applications have thus far had anything like the success of SMS (Short Message Service) text messaging. However *mobile learning* appears to be a promising mobile application, being able to enhance learning in context via mobile devices and applications designed to support the user's learning processes. In the evolving educational landscape, mobile devices appear to be an ideal solution to support context-dependent learning (Ryu and Parsons 2008), since by definition they are highly *portable*, *personal* and *always-carried*. In this regard, though mobile phones and game consoles were once banned as a distraction in classes, now education providers are beginning to regard such devices as potential learning platforms. Those that double as Internet platforms and various types of media player provide students with a portable learning tool where mobility is perceived as the central concern of mobile learning.

Mobility can positively influence learners to be physically able to tune in to their own social environment while they are learning. The '*anytime* and *anywhere*' learning opportunity not only relates to the physical device, but also requires us to consider the learner's own mobility (McNeal and van't Hooft 2006). Such nomadic learners spend more and more time on the move, so it is appropriate that education might also be required to move from place to place. However, this mobility may have negative influences on learning performance, in that it inevitably asks the learner to attend to more than one information source when using the mobile device. For instance, while you are walking through a busy street, you need to pay attention to the whole street environment in order to avoid getting lost, run over, or hitting other pedestrians. The limits of our attention resources sometimes describe our limited ability to time-share the performance of two or more concurrent tasks, and sometimes describe the limits in integrating multiple information sources on the mobile device. It is of course difficult to approach mobile learning designs that embrace the concerns of human attention and its related limitations, but nevertheless the designer should bear in mind that mobile learning will often be used whilst the learner is on the go, or at least not in the entirely static situation that most e-learning systems have been built upon.

In effect, not all kinds of design patterns or experiences from desktop-based learning systems are appropriate for mobile learning. Therefore we should not simply apply known design requirements from desktop e-learning in the mobile learning context. The *de facto* standards that determine learning content design for systems with large screen, keyboards, and mice are now so familiar, that there is a danger that the large amount of analytic and empirical educational technology research that went into them might be forgotten. This article therefore goes back to re-address some of the basic research questions of learning technologies.

2. WORKING MEMORY AND MOBILE LEARNING

One notably different feature between mobile users and desktop computer users is that most mobile users are not sitting attentively at a desk, which means they are socially engaging with other activities and moving. They may be in rush-hour traffic, in a meeting, in class, on a train, walking down the street, in environments that are interruptive like never before. Thanks to this mobility, navigation through the physical world is a task that uses the majority of a person's attention resources. Of course, many of us may not be mobile while actually using a mobile phone or device; however, it appears that we readily move between instances of using the mobile device. Therefore, whilst human attention resources would also be an essential concern of e-learning, they are even more important in m-learning thanks to the issue of mobility.

Doolittle *et al.* (2008) empirically demonstrated that learning with a mobile-based multimedia learning environment is sensitive to individual differences in attention. Their research pinpoints human *working memory* as an essential factor in dictating the success of mobile learning, which may suggest that mobile learners would not be able to perform highly task-focused (or onerous) learning activities. However our psychological understanding is that working memory is complex, so a single approach would not be sufficient to see the full effects of the attention control mechanism. Working memory (Baddeley 1986) consists of the *phonological loop* and *visuo-spatial scratch pad*, and though they are equally important in controlling attention, the latter seems to be more significant to mobile learning, in that the *phonological loop* is a speech-based system that is implicated in the online processing of verbal material; in contrast, the *visuo-spatial scratch pad* is posited to serve the maintenance of visual and spatial information over the short term.

With regard to *visuo-spatial working memory*, Eliot and Smith (1983) claimed that human spatial ability entails visual problem-solving or tasks that require individuals to estimate, predict, or judge the relationships among figures or objects in different contexts. More specifically, it relates to individuals' abilities to search the visual field, apprehend forms, shapes, and positions of objects, form mental representations of them and manipulate these representations mentally (Carroll 1993). We might infer that this type of working memory would be important in mobile learning situations where learners often have to cope with multiple spatial tasks. To empirically see the potential effect of visuo-spatial working memory, Stanney and Salvendy (1995) developed two different interfaces that were used to test the information search performance of high and low spatial individuals. The results showed that high spatial individuals outperformed low spatial individuals in mentally constructing a model of the organization and structure of embedded learning information. Further, Sjölinder (1998) suggested that individuals with low spatial ability seem to be more directed to the semantic content rather than other learning information, and in a similar vein, animations with on-screen narrative text may result in difficulties for learners with low spatial ability (Doolittle et al 2008). Certain mobile learning designs may be more effective for some types of learner than others, therefore one characteristic of individual difference, the effect of spatial working memory, is empirically investigated in this paper.

3. METHOD

The experiment was based on our understanding of the relationship between spatial working memory and learning content design, and in particular, the sensitivity of learners to mobile learning through their spatial working memory capability. To empirically investigate this research question, two mobile learning systems, one using plain text and the other, media-rich, using animations and narratives, were created. It was hypothesized that those who had low spatial capability would not gain the same benefits from the media-rich mobile learning system, and we further assumed that high spatial ability would be an essential component of individual difference, impacting on mobile learning design.

A total of 32 students from Massey University voluntarily participated in the study, having a similar tertiary educational background (IT and Computer Science majors), in the age range 21 to 24, with an even gender distribution.

The first step was to classify the participants into two groups (high spatial and low spatial) using the mental rotation test (Shephard and Metzler 1971). Then, half of those having high spatial working memory were asked to use the plain text m-learning system, and the other half used the multimedia m-learning system, with a similar distribution for the lower spatial individuals. In addition, all the participants took part in an e-learning session as a control condition.

The experimental design was a 2 by 2 within-subjects factorial. *Mobile learning systems* (plain texts vs. multimedia – animations and narratives), and *spatial working memory capabilities* (high vs. low) were the independent variables. The dependent variable, the scores from the two problem solving questions, was used to assess the learning performance after each learning session.

All the participants were firstly asked to attend a mental rotation test (Shephard and Metzler 1971), as shown in Figure 1. The four options from the right hand side of the figure are either altered in shape, or rotated by an angle, or both, compared with the example on the left. The task for each participant was to find two fully matched rotated shapes from the four options. They were given ten questions to complete in six minutes.

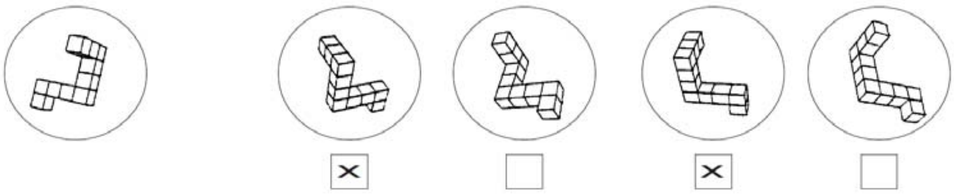

Figure 1. Mental Rotation Test. Participants were asked to find shapes from four options on the right that were identical to the shape on the left. (Reprinted from Encarta© Microsoft Corporation)

After each participant completed the mental rotation test, he or she was asked to explore an e-learning system for five minutes. This system comprised conventional web pages, containing no animations or other content types that might be considered media-rich. The e-learning material explained *Fitts' law* (MacKenzie 1992), a well-known model in HCI (Human-Computer Interaction) to describe the *index of difficulty* in movement based on motor tasks. After this learning session, the participants were given two problem-solving questions that required the application of Fitts' law. After a one week interval, our participants were invited back again, and this time were given only one of the two mobile learning systems that delivered the same learning content (i.e., Fitts' law). The participants explored the given mobile learning system for five minutes and were then given two problem-solving questions that were much harder to answer than those used in the earlier e-learning session.

4. RESULTS

To classify our participants, the face value of 60 (out of 100) of the mental rotation test score was used, as indicated in many related studies. A total of sixteen participants were assigned to the high spatial ability group and the other sixteen were classified as low spatial ability individuals.

Figure 2 gives the mean learning performances in both e-learning and m-learning session. As one can see from Figure 2(a), there was no significant difference between the two different spatial groups with the e-learning material ($F_{1,30} = 0.12$, n.s.). However, Figure 2(b) shows a rather significant difference in the mobile learning session by the same participants ($F_{1,30} = 5.52$, $p \leq .05$).

(a) (b)

Figure 2. Learning performance between the high and low spatial ability: (a) e-learning and (b) m-learning

Another hypothesis in this experiment was that as the media-rich learning material seems to consume more spatial working memory, the participants who have high spatial ability (mean = 75.00) would outperform those who have lower spatial ability (mean = 43.75). This difference was statistically significant with our participants ($F_{1,14}$= 3.52, $p \leq .05$) but there was no significant difference between the two groups with the plain-text m-learning material ($F_{1,14}$= 2.03, n.s). This performance distinction between the two systems would imply that the multimedia mobile learning system is more beneficial to high spatial individuals.

5. CONCLUSION

Taken together our results demonstrate that the learner's spatial working memory combined with the mobile learning medium can influence learning performance. It is of course difficult to generalize from the conditions of the experiment to more general mobile learning content design. However, the data can be taken to suggest that, at the very least, care is needed when designing mobile learning content and that individual differences in learners' spatial working memory need to be considered. Those who do not have high spatial ability may not gain the same benefit from a given system as those who do. Spatial working memory is therefore an important characteristic to be considered in m-learning content design. Of course to confirm this guideline, many other studies are undoubtedly needed.

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