Computers in Human Behavior 35 (2014) 339–349

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

Research Report

# Improving learning from animated soccer scenes: Evidence for the expertise reversal effect

Aïmen Khacharem [a,b,c,*], Bachir Zoudji [b,c], Ingrid A.E. Spanjers [d], Slava Kalyuga [e]

[a] UFR STAPS, University of Orléans, F-45100 Orléans, France
[b] Univ Lille Nord de France, F-59000 Lille, France
[c] UVHC, DeVisu, F-59313 Valenciennes, France
[d] Department of Educational Development and Research, School of Health Professions Education, Maastricht University, The Netherlands
[e] School of Education, University of New South Wales, Sydney, NSW 2052, Australia

ARTICLE INFO

*Article history:*
Available online 29 March 2014

*Keywords:*
Cognitive load theory
Instructional designs
Animations
Prior knowledge
Soccer

ABSTRACT

In two experiments, we investigated how animation of play (soccer) should be designed in order to avoid the high cognitive load due to the fleeting nature of information. Using static pictures and altering the animation's presentation speed have been proposed as instructional strategies to reduce learners' cognitive load. In the first experiment, we tested the effect of static vs. animated presentations on learning. The results indicated that novices benefited more from the static presentation whereas experts benefited more from the animated presentation. The second experiment investigated the effect of low vs. normal vs. high levels of presentation speed on learning. The results showed that novices profited more from the low presentation speed while experts profited more from the normal and high presentation speeds. Thus both experiments demonstrated the occurrences of the expertise reversal effect. Findings suggest that the effectiveness of instructional strategies depends on levels of soccer players' expertise.



## 1. Introduction

The ability to learn a complex game pattern is indispensable for successful performance in open skill team sports such as soccer. Visualizations are considered as one of the most fundamental and powerful tools to enable players to learn these game patterns efficiently, because they can deliver the visuospatial information about the game in a direct and parsimonious way, and thereby facilitate reasoning processes grounded in perception (Goldstone & Son, 2005; Schwartz, 1995). In recent years, dynamic visualizations such as animations (e.g., Garsoffky, Schwan, & Hesse, 2002) or videos (e.g., North, Ward, Ericsson, & Williams, 2011), have been extensively employed by soccer coaches and researchers examining soccer. Such visualizations extend the possibilities of traditional instructional media (e.g., sets of static pictures, written/oral explanations) by explicitly representing dynamic characteristics of game patterns (motion, acceleration, and timing). However, learning from dynamic visualizations could be a challenging task, as information is often fleeting (Ayres & Paas, 2007; Moreno & Mayer, 2007). Visual information essential for understanding the game situation may disappear from sight before the learner has time to adequately process it or integrate it with new information. Consequently, players may miss crucial information, and, therefore, fail to accurately understand the content communicated by the coach (Paas, Renkl, & Sweller, 2003).

Several studies have suggested ways to avoid or reduce the high perceptual-cognitive demands imposed by the fleeting nature of animations, such as the use of static pictures instead of animations (Hegarty, Kriz, & Cate, 2003; Mayer, Hegarty, Mayer, & Campbell, 2005) or adjusting animations' presentation speed (De Koning, Tabbers, Rikers, & Paas, 2011; Fischer, Lowe, & Schwan, 2008; Fischer & Schwan, 2010). However, according to the expertise reversal effect (Kalyuga, 2007; Kalyuga, Ayres, Chandler, & Sweller, 2003), levels of learner expertise could modulate the effectiveness of such means for enhancing learning. Therefore, it could be predicted that the effectiveness of using static pictures rather than animations and adjusting animations' presentation speed when instructing players about soccer scenes might depend on the players' levels of expertise in soccer.

In this study, a recall reconstruction-paradigm (Chase & Simon, 1973) and mental effort ratings (Paas, 1992) were used to investigate how well, easy and quickly soccer scenes of play were learned from animations and static pictures (Experiment 1) and from animations with different levels of presentation speed (Experiment 2),

* Corresponding author at: UFR STAPS, Université d'Orléans, Allée du Château, 45100 Orléans, France. Tel.: +33 642103201.

*E-mail address:* aimen.khacharem@gmail.com (A. Khacharem).

http://dx.doi.org/10.1016/j.chb.2014.03.021
0747-5632/

and to investigate whether the effectiveness of these instructional manipulations would depend on levels of player expertise (both experiments).

### *1.1. Learning from complex animations*

Schnotz and Lowe (2008, p. 304) define an animation as "a pictorial display that changes its structure or other properties over time and which triggers the perception of a continuous change". Intuitively, animations are assumed to be the best media for training in team ball sports, because they portray dynamic or change-related information inherent to scenes of play in a natural and realistic way (Mann, Williams, Ward, & Janelle, 2007). However, several nonsporting studies have failed to confirm this intuitive assumption (e.g. Hegarty et al., 2003; Mayer, DeLeeuw, & Ayres, 2007; Mayer et al., 2005). As Tversky, Bauer-Morrison, and Bétrancourt (2002) indicated, the ineffectiveness of animations could be related to their frequent violation of the "apprehension principle" according to which animations should not be too complex or too fast to be accurately perceived and understood by the learners.

Furthermore, cognitive load theory (Sweller, 2010; Sweller, Van Merriënboer, & Paas, 1998; Van Merriënboer & Sweller, 2005) argues that instructional animations could be ineffective because they often impose high extraneous (unnecessary) cognitive load due to their fleeting nature (transient information effect; e.g., Sweller, Ayres, & Kalyuga, 2011). Because animations change continuously over time, learners may not be able to process and integrate specific key elements of information that occur within the flow of information (e.g., Rasch & Schnotz, 2009). Such processing and integration of information take place in working memory (WM). It is well known that WM is extremely limited in both duration and capacity when processing novel information (Baddeley, 2003). Working memory can manipulate no more than a few interconnected elements of information simultaneously (Cowan, 2001), and this information is usually lost from WM within a few seconds if it is not intentionally rehearsed (Peterson & Peterson, 1959). These limitations of WM pose a problem when dealing with fleeting information, such as the information presented in an animation. When studying a continuous animation, learners are required to temporally hold information from earlier frames in WM to be able to connect it with information presented on later frames in order to form a coherent internal representation of the shown content (Moreno & Mayer, 2007). The activities needed to deal with fleeting information can overwhelm WM, and as a consequence, hinder the learning process and negatively affect learning outcomes (Ayres & Paas, 2007; Sweller et al., 2011).

Two possible ways to avoid the problems related to the fleeting nature of animation are displaying key states of the system with static pictures (e.g., Bétrancourt, 2005; Bétrancourt, Dillenbourg, & Clavien, 2008; Mayer et al., 2005; Schnotz & Lowe, 2008; Boucheix & Schneider, 2009) and adjusting the animations' playing speed (e.g., De Koning et al., 2011; Fischer & Schwan, 2010). Firstly, displaying the key states of the system simultaneously with static pictures provides learners with a permanent visual representation of the information (Arguel & Jamet, 2009) and, therefore, offers the possibility to revisit and to reinspect parts of the display any required number of times (Hegarty, 2004). This is difficult, or even impossible, when the information is presented in an animation. However, Höffler and Leutner (2007) drew the more optimistic conclusion that learning from animations is more effective than learning from static pictures, particularly, if the content to be communicated is realistic (as opposed to schematic), representational (as opposed to decorational), and involves procedural-motor knowledge. In addition, research studies in Aptitude Treatment Interactions (ATI) have identified some factors that may moderate the effectiveness of visualization formats. These factors include spatial ability (Hays, 1996; Höffler & Leutner, 2011), cognitive style (Höffler, Prechtl, & Nerdel, 2010), need for cognition (Kim, Yoon, Whang, Tversky, & Morrison, 2007) and prior knowledge (Kalyuga, 2008). The last factor (i.e., prior knowledge) will be a focus of the current investigation.

Secondly, decreasing the animations' presentation speed may provide learners with more time to perform the necessary processing in WM, thus reducing the probability that key information is missed (De Koning et al., 2011). In addition, decreasing the speed of presentation alters the perceptibility profile of the presented information, so that changes that occur at the micro level of the animated system or procedure become more perceivable and accessible, thereby making its apprehension more likely (Meyer, Rasch, & Schnotz, 2010; Schnotz & Lowe, 2008).

### *1.2. The expertise reversal effect*

A number of studies have shown that designs and techniques that are effective for learners with lower levels of prior knowledge (novices), might not be effective for learners with higher levels of prior knowledge (experts), and vice versa. The reversal in the relative effectiveness of instructional methods as levels of learner knowledge in a domain change has been referred to as the expertise reversal effect (Kalyuga, 2007; Kalyuga et al., 2003). This effect represents a clear example of ATI (Cronbach & Snow, 1977). It has been suggested that when the presented information needs to be integrated in working memory with already available knowledge structures of learners, this integration process may impose an additional cognitive overload resulting in the expertise reversal effect. For example, presenting detailed instructional explanations to knowledgeable learners (especially if they cannot ignore or otherwise avoid processing these explanations) may trigger their cognitive activities that support construction of knowledge that they already have thus interfering with rapid retrieval and fluent application of available knowledge structures in Long-Term Memory (LTM). Such redundant activities may overload working memory resulting in reduced learning outcomes. The expertise reversal effect has been identified in many studies with a wide range of instructional techniques (procedures) and learners, and has been reported either as a complete reversal (i.e., disordinal, crossover interaction) with significant differences for both novices and experts or, as a partial reversal (i.e., ordinal, non-crossover interaction) with non-significant differences for novices or experts, but with a significant interaction (Kalyuga & Renkl, 2010). The major implication of these studies is the necessity to tailor the learning material as learners acquire more expertise in a specific domain.

Kalyuga (2008) provided evidence for an expertise reversal effect using animated or static diagrams demonstrating transformations of simple linear and quadratic functions in high school mathematics. The results indicated a significant interaction between levels of learner expertise and learning materials. Novice learners profited more from a set of equivalent static pictures depicting the major stages of the procedure. However, animations were more beneficial for expert learners who have already developed a sufficient knowledge base (already stored in LTM) for dealing with the fleeting nature of the animation.

This result stands in contrast to the assumption of Höffler (2010) stating that learners with low prior knowledge might benefit from learning with animations, while learners with high prior knowledge might not. Animations might act as a "cognitive prosthetic" (Hegarty & Kriz, 2008) for learners with low prior knowledge since the visualization provides an external representation system/procedure that helps them to build an adequate mental model. Oppositely, high prior knowledge learners might not profit from animation as they are able to perform mental (internal)