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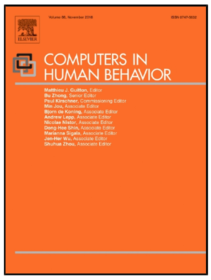

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Improving Instructions in Educational Computer Games: Exploring the Relations Between Goal Specificity, Flow Experience and Learning Outcomes

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Abstract

We explored the relationship between goal specificity, flow experience and learning outcomes in educational computer games (ECGs). Our first aim was to analyze how goal specificity affects learning performances and reading activities in an ECG. Our second aim was to assess the effects of flow experience on learning with an ECG. Concerning our first aim, results indicated that a nonspecific goal, as opposed to one that is specifically defined in the task, enhances comprehension, but not memorization. It also affects reading strategies, leading to less scrolling back. Concerning our second aim, results highlighted a beneficial influence of flow experience on both memorization and comprehension. We did not observe any effect of goal specificity on flow experience. The results for goal specificity are discussed with respect to the dual space and cognitive load explanations. The relevance of using flow experience to assess motivation in ECGs is also addressed.

Keywords: media in education, educational computer game, digital game-based learning, instructions, goal-specificity effect, interactive learning environments

Highlights

- We explored the links between goal specificity, flow and learning outcomes in ECGs.
- A goal-specific effect was found for comprehension but not for memorization.
- A specific goal produced more scrolling back, a suboptimal reading strategy.
- Flow experience positively influenced memorization and comprehension.

1 Introduction

Educational computer games (ECGs) are intended to promote learning while creating appealing experiences for learners. More specifically, their main purpose is to support *digital game-based learning*, which refers to competitive activities intended to bring about a substantial change in a learner's knowledge or skills (Mayer, 2014a). Many authors have attempted to define ECGs (e.g., Clark & Mayer, 2008; Erhel & Jamet, 2015; Michael & Chen, 2006; Vogel et al., 2006; Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013). According to Prensky (2001), this medium can be seen as balancing serious learning and interactive entertainment. Mayer (2014a) proposed a more accurate definition, resting on five main characteristics: 1) *games are rule based*, in that they represent a simulated system based on causal rules that players can master; 2) *games are responsive*, in that they respond promptly and clearly to players' actions; 3) *games are challenging*, in that they offer appropriate challenges, provide opportunities for successfully performing difficult tasks; 4) *games are cumulative*, in that they reflect the players' previous actions and allow them to assess their progress toward goals; and 5) *games are inviting*, in that they are fun to play, interesting and appealing, thereby motivating players to keep on playing.

Research on ECGs can be divided into three approaches (Mayer, 2014a): *a cognitive consequence approach* focusing on what is learned from playing computer games; a *media comparison approach* investigating whether people learn better when the game is on a computer rather than in a conventional medium (see Nimwegen, van Oostendorp, & van der Spek, 2013, for a review) and the *added-value approach* assessing how various features of a game can affect learning and motivation. Regarding the latter, ECGs contain *game features* that are used to motivate learners to engage in game playing, and *instructional features* that are intended to foster appropriate cognitive processes during game playing. To understand how these game and instructional features may improve learning, this approach draws heavily on Mayer (2014b)'s *cognitive theory of multimedia learning*. This theory states that learners can only process small amounts of information at a time. This information undergoes dual-channel processing, where one channel is dedicated to visual materials, and the other to verbal materials. Meaningful learning occurs when learners engage actively in three successive processing steps: *selecting* relevant incoming information; *organizing* the selected information into coherent cognitive representations; and *integrating* the cognitive representations with relevant prior knowledge. Achieving these three processing steps depends on the cognitive demands imposed by the game and instructional features, which can be divided into 1) *extraneous processing*, which does not serve the instructional goal and is caused by poor instructional design, 2) *essential processing*, which intended to mentally represent the essential material and is contingent upon the complexity of the material, and 3) *generative processing*, which aims at reaching a deeper understanding and is contingent upon the learner's motivations. In order to promote meaningful learning, a game design should minimize extraneous processing, manage essential processing, and foster generative processing (Mayer, 2014b). In this context, *meaningful learning* (also known as *deep learning*) refers to "the critical analysis of new ideas, linking them to already known concepts and principles, and leads to understanding and long-term retention of concepts so that they can be used for problem solving in unfamiliar contexts". It is often contrasted with *surface learning*, which corresponds to "the tacit acceptance of information and memorization as isolated and unlinked facts" (Kester, Kirschner, & Corbalan, 2007).

The purpose of the value-added approach is therefore to explore how adding different features can foster deep learning and motivation. Many authors have adopted this approach to examine the beneficial effects of personalization (Moreno & Mayer, 2000, 2004), self-explanation

(Johnson & Mayer, 2010), competition (DeLeeuw & Mayer, 2011), and feedback (Leutner, 1993; Mayer & Johnson, 2010; Moreno & Mayer, 2005). However, few studies have explored whether game instructions can foster deep learning with ECGs.

1.1 Instructions in ECGs: exploring the goal-specificity effect

Although several studies have explored how the instructions feature influences learning and motivation in ECGs (Erhel & Jamet, 2013, 2015; Hawlitschek & Joeckel, 2017), as far as we know, only few studies have compared the effects of specific versus nonspecific instructions in ECGs (Miller, Lehman, & Koedinger, 1999 ; Nebel, Schneider, Schledjewski, & Rey, 2016).

One relevant framework exploring the goal-oriented behavior is the *Goal Setting Theory* used mainly in the industrial / organizational context (Locke & Latham, 2006). This theory assumes that some specific goals lead to a higher level of task performances than do easy or vague goals, (i.e., *do one's best*). In other words, high or difficult goals should be more motivating because they require more effort to attain the desired state. To an extent, this theory is interesting in the educational context because these specific or difficult goals should encourage individual to use their existing abilities, mobilize their knowledge and exert effort to collect new knowledge. However, in the context of learning activities, Locke and Latham (2006) acknowledged that some specific goals do not systematically lead to higher performances. This phenomenon, called "the tunnel vision", occurs when the individuals are focused on reaching the goal instead of reaching the skills required to achieve it.

This particular situation has been well described in the cognitive load theory with the framework of *goal-specificity effect*, also known as the *goal-free effect.* According to Sweller and Levine (1982), goal specificity is the extent to which a set of goals is clearly defined for a person. The goal-specificity effect can be observed when a conventional problem with a specific goal is replaced by a problem with no specifically defined goal (Sweller, Ayres, & Kalyuga, 2011). Research on this effect has shown that providing a nonspecific goal during problem solving leads to better learning outcomes than providing a more specific goal that requires a specific state to be attained. This effect has been demonstrated for various kinds of problems, including geometry (Ayres, 1993; Ayres & Sweller, 1990), arithmetic (Sweller, Mawer, & Ward, 1983), mazes (Paas, Camp, & Rikers, 2001; Sweller & Levine, 1982), and physics (Künsting, Wirth, & Paas, 2011; Miller et al., 1999; Wirth, Künsting, & Leutner, 2009). Overall, these studies found that nonspecific goals had an advantage over specific ones.

Several alternative explanations for the goal-specificity effect have been put forward in the literature (Sweller et al., 2011; Wirth et al., 2009). Simon and Lea (1974) stated that a problem space can be divide into a *rule space*, in which hypotheses are formulated and tested, and *an instance space*, in which problem-solving moves are made. Drawing on this idea, Vollmeyer and Burns (2002) put forward their *dual-space explanation*, in which they assumed that different strategies are triggered in a specific versus nonspecific goal environment. A specific goal encourages searching of the instance space, triggering a pure problem-solving strategy (i.e., learners try to reach a given state of a problem without understanding the whole system), whereas a nonspecific goal elicits searching of the rule space devoted to the generation and testing of hypotheses, triggering a learning strategy (i.e., learners try to discover how the whole system works). In the context of instructional design, a learning strategy is more desirable during learning activities, as it is more likely to create or modify cognitive representations. According to the dual-space explanation, the goal-specificity effect can be accounted for in terms of strategies. According to another approach, however, named the *cognitive load explanation*, it can be attributed to the different amounts of cognitive load imposed by specific versus nonspecific goals.

For their part, Sweller et al. (2011) asserted that novice learners work backwards from the goal to the givens by implementing *a means-ends analysis* (Newell & Simon, 1972). This analysis, which is a pure problem-solving strategy, consists in considering "the problem givens, the goal, the differences between the givens and the goal and the problem-solving operators that might reduce those differences" (Sweller et al., 2011, p. 90). There is a high level of interactivity between these components, suggesting that recourse to a *means-ends analysis* results in a higher cognitive demand, straining working memory and having a detrimental effect on learning. The main disadvantage of setting a specific goal is precisely that it encourages the application of a *means-ends analysis* (Künsting et al., 2011; Sweller et al., 2011; Wirth et al., 2009). One way of avoiding this kind of analysis is thus to provide a nonspecific goal. As this goal does not specify any endpoint for a problem, it releases cognitive resources in working memory that can be devoted to acquiring new cognitive representations or restructuring existing ones. Far from being mutually exclusive, the *dual space* and *cognitive load* explanations are fully compatible. According to Sweller et al. (2011), learners given a specific goal tend to ignore the rule space because their working memory is overwhelmed by searching the instance space.

As previously mentioned, to the best of our knowledge, few studies have so far compared specific and nonspecific goals in ECGs. Miller et al. (1999) used an interactive game simulating the movement of an electrically charged particle to compare three goal conditions: a *nonspecific* condition in which students had to experiment and learn as much as they could in the game; a *specific condition* where students had to reach a specific state in the game; and a *specific-path* condition in which students had to reach a specific state in the game using a solution path displayed in a worked example. Results showed that students in the nonspecific and specific-path conditions outperformed the students in the specific condition on a physics test in the game. More recently, Nebel, Schneider, Schledjewski and Rey (2016) made an attempt to contrast three forms of goals using the MINECRAFT sandbox game. Two of these goals were taken from goal setting theory (specific learning goal and specific performance goal), while the third goal was taken from cognitive load theory (nonspecific goal; i.e., goal-free effect). Their results demonstrated that learners perceived a higher extraneous cognitive load, owing to the support in the specific performance goal group compared with the specific learning goal group. However, the results revealed no significant difference from the goal-free group on extraneous cognitive load. Regarding the fun variable, results showed that the learning goal group experienced higher perceived fun than the goal-free group. No significant difference was observed between the two specific goal groups and the goal-free group on either learning performances or motivation. Further studies are needed to validate the existence of a goal-specificity effect in ECGs. In most previous studies investigating the goal specificity effect, variables measuring motivation were omitted. However, these variables have already been tested in other studies manipulating different forms of goals (Erhel & Jamet, 2015; Hawlitschek & Joeckel, 2017). As ECG playing is characterized by a high level of motivation (see, for example, Egenfeldt-Nielsen, 2006; Garris, Ahlers, & Driskell, 2002; Hawlitschek & Joeckel, 2017; Malone & Lepper, 1987; Prensky, 2001), we argued that an investigation of goal specificity in ECGs should systematically encompass motivation variables.

1.2 How can motivation contribute to learning in educational computer games?

According to Malone and Lepper (1987), the motivational power of learning games relies on three elements: 1) *challenge*, in that a game should incorporate an optimum level of difficulty that does not overcome the player's current competence; 2) *fantasy*, in that a game should call up mental images in an entertaining universe that fully integrates the content to learn; and 3) *curiosity*, in that a game should offer opportunities for players to enhance their knowledge. These three elements play a central role in triggering motivation during acquisition (see, for example, Annetta, Minogue, Holmes, & Cheng, 2009; Lieberman, 2006; Vandercruysse, Vandewaetere, & Clarebout, 2012). *Motivation* can be described as a set of physiological processes that influences the direction, vigor and persistence of behaviors (Moos & Marroquin, 2010). Regarding ECGs, motivation is often addressed from the perspective of engagement. In their review of literature, Eccles and Wigfield (2002) described two theories dealing with the reasons for engaging in achievement tasks: self-determination theory (Deci & Ryan, 1985, 2000, 2002) and flow theory (Csikszentmihalyi, 1988; Nakamura & Csikszentmihalyi, 2009). *Self-determination theory* conceptualizes motivation as the ultimate reason for achieving a behavior through self-determination. According to this theory, the reasons for engaging in activities range from external to fully internalized, the latter corresponding to intrinsic motivation. *Intrinsic motivation* refers to the inner desire to engage in a task for reasons of interest or enjoyment, or even because of the challenge it offers (Deci & Ryan, 2000; Martens, Gulikers, & Bastiaens, 2004). In order to trigger a high level of intrinsic motivation, Mayer (2014b) recommends paying attention to the quality of the features used in ECGs. If learners are offered the possibility of controlling the game, receiving feedback on their performances, or even personalizing the game, they display greater motivational investment. In other words, intrinsic motivation seems to mediate the effect of instructional support on learning outcomes. This is exactly the position shared by Hawlitschek and Joeckel (2017), who hypothesized that intrinsic motivation mediates the effect of a learning instruction on learning outcomes. However, their results failed to show any significant mediation effect.

In the context of digital game-based learning, a second promising theory is *flow* theory (Csikszentmihalyi, 1988), whereby individuals engage in activities to achieve an immediate optimal experience. This optimal experience, also called *flow*, occurs when an individual feels concentration, fun and interest while engaging in an activity. When in flow, individuals work at full capacity, experiencing an intense state of concentration and a high level of cognitive absorption. This optimal experience is possible when individuals perceive an adequate balance between the challenges related to the task and their own skills. According to Nakamura and Csikszentmihalyi (2009), the flow state is intrinsically rewarding, meaning that individuals seek to replicate flow experiences. Flow is therefore regarded as a promising means of encouraging learners to commit to learning activities. Recently, several studies have highlighted a positive relation between flow and learning outcomes (Admiraal, Huizenga, Akkerman, & Dam, 2011; Brom et al., 2014; Hou & Li, 2014; Hung, Sun, & Yu, 2015). For example, using an integrated behavioral pattern analysis, Hou (2015) showed that learners with a high level of flow exhibited a deeper reflective process. In line with these previous results, Hamari et al. (2016) observed that learning games with an increasing level of challenge create conditions for both flow and engagement. They also showed that flow is positively associated with learning performances. In an ECG context, these findings are interesting because they underline that some game features (i.e., challenge) help to sustain flow experience and positively influence learning achievement. In the present study, we argued that flow experience may be directly affected by another game feature, namely the instructions provided in the game, and more particularly, goal specificity. A study by Schweickle, Groves, Vella, and Swann (2017) provided some initial support for this notion, by demonstrating that learners performing a cognitive task (e.g., letter and number identification task) who are given an open (i.e., nonspecific) goal experience a higher level of flow than those who receive a specific goal.

1.3 Overview of the present study

We sought to extend Miller et al. (1999)'s research on the goal-specificity effect in ECGs, and more particularly to observe its benefits in terms of learning outcomes and motivation. Our first aim was to demonstrate the goal-specificity effect on learning performances and reading activities. To this end, we provided a sample of students with two types of instruction, either 1) a nonspecific goal instruction asking them to work on a game-based course about the birth and development of typology, or 2) a specific goal instruction asking them to work on the same game-based course so that they could fill in an historical timeline on paper. After reading the instruction they had been given, all the learners played the same ECG and underwent a series of measures of learning outcomes and flow.

Hypothesis 1: an ECG instruction with a specific goal has a negative effect on memorization, compared with an instruction with a nonspecific goal.

More specifically, we hypothesized that an instruction with a specific goal triggers a means-ends analysis. This pure problem-solving strategy overwhelms working memory, as learners have to simultaneously consider several givens and goals. Consequently, they are unable to engage sufficient cognitive resources in a learning strategy, thus impairing memorization. By contrast, a nonspecific goal leads to higher memorization scores, as it imposes a lower cost on working memory, thus favoring a learning strategy.

Hypothesis 2: an ECG instruction with a specific goal has a negative effect on comprehension, compared with an instruction featuring a nonspecific goal.

More specifically, in a specific goal condition, the *means-ends analysis* places a strain on working memory because learners have to simultaneously consider several givens and goals to complete the historical timeline. Considering these parameters interferes with the implementation of a learning strategy and impairs the processing that is essential to mental model elaboration (i.e., comprehension). By contrast, a nonspecific goal creates the optimum conditions for implementing a learning strategy, resulting in comprehension (i.e., meaningful learning).

Hypothesis 3a: an ECG instruction with a specific goal has a negative effect on reading strategy, entailing more scrollbacks compared with an instruction featuring a nonspecific goal.

More specifically, we predicted that the means-ends analysis would lead learners in the specific goal condition to engage in more scrolling back, in their intensive search for items to complete the historical timeline.

In order to explore reading strategies, we also calculated the mean amount of time spent on each page of instructional content. Concerning this variable, we adopted an exploratory approach, as two plausible scenarios could occur concomitantly.

Hypothesis 3b: compared with a nonspecific goal, the specific goal of filling out a timeline encourages learners to engage in scanning, resulting in less consultation time per page. Then again, it may induce more scrolling back, thus increasing the consultation time per page.

In the present study, we argued that individuals probably engage in learning games to enjoy an immediate optimal experience. Learning games are intrinsically motivational because they elicit challenge, curiosity and fantasy (Malone & Lepper, 1987), and these characteristics are clearly highly compatible with the achievement of a flow state. Our second aim was thus to show that flow experience plays a central role in learning with an ECG.

Hypothesis 4: when the goal specificity factor is controlled, flow experience positively influences learning performances (memorization and comprehension).

Several studies have reported a positive influence of flow experience on learning outcomes (see, for example, Hamari et al., 2016; Hou, 2015). In accordance with these studies, we assumed that experiencing a high level of flow would elicit better learning performance.

Hypothesis 5a: an ECG instruction with a specific goal has a negative effect on flow experience, compared with an instruction featuring a nonspecific goal.

In accordance with Mayer (2014, p. 75), we assumed that the quality of game features influences motivational investment and, more precisely, the level of flow experience. Among the possible features, we chose to work on the nature of instructions with respect to goal specificity. As far as we know, only one study has so far assessed the impact of goal specificity on flow experience. Schweickle et al. (2017) demonstrated that a nonspecific goal provided during a cognitive task raises the level of flow experience. Although our context was slightly different, we assumed that goal specificity would influence the level of flow experience in our learning game.

If this were indeed the case, we further assumed that:

Hypothesis 5b: the level of flow experience mediates the effect of goal specificity on learning performances (memorization and comprehension).

More specifically, some authors have suggested that motivational investment in game-based learning is a moderating variable, as motivation influences learning performances

(Vandercruysse et al., 2012; Wouters & van Oostendorp, 2013). For their part, Hawlitschek and Joeckel (2017) attempted to demonstrate that intrinsic motivation mediates the effect of some instructions (i.e., learning vs. entertainment) on learning outcomes. However, they failed to find any significant mediation effect. As we considered that flow experience was a more accurate construct for studying motivation in ECG, we explored whether optimal experience mediates the relationship between the goal-specificity effect and learning outcomes.

2 Method

2.1 Participants

Participants were 109 psychology undergraduates from Rennes University. Our final sample was selected at the end of the experiment, using an instruction recognition task (i.e. "Which of these instructions were you given?"). This verification procedure was designed to ensure that players had properly read the instruction provided at the start of the game. It revealed that 18 participants failed to recognize the instruction. We therefore included 91 participants (12 men and 79 women; mean age = 19.49 years, *SD* = 2.26) in our analysis. We conducted an experimental study using two groups: a specific goal group composed of 44 participants (6 men, 38 women; mean age = 19.36 years, *SD* = 1.49), and a nonspecific group made up of 47 participants (6 men, 41 women; mean age = 19.61 years, *SD* = 2.81).

2.2 Material

2.2.1 Type:rider educational game

Our digital game-based learning was conducted with Type:rider, a typographical odyssey created by Cosmografik and produced by Ex Nihilo Studio and Arte France (http://typerider.arte.tv/#/jeu). This game introduces players to the history of typography by propelling a colon (i.e., two dots) in the mysterious game of Type:rider. Basically, this game involves guiding the colon across its environment via suspended platforms and over obstacles (see Fig. 1). Players control its jumps with the keyboard, making sure it does not miss any necessary ones. This game comes in nine chapters and can be beaten in approximately 2h30. For convenience, the players in our sample only had to complete the first two chapters, "Origins" and "Gothic". In these chapters, the players had to guide the colon over obstacles to collect 26 letters. When certain letters were collected, the game was put on hold, and the players accessed a virtual ancient book containing informational content about typography. This book contained 12 separate texts on typography (no hypertext structure), and the learners could scroll up and down each page, using arrows. They could stop reading whenever they wanted and return to the game to collect new letters. The page length was comparable for the two chapters.

Figure 1

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For the purpose of our experiment, this videogame was encapsulated in a slideshow developed with Microsoft PowerPoint, in order to provide two different instructions directly inspired by Vollmeyer and Burns (2002). The *specific goal instruction* ("Work on the following game-based course so that you can correctly fill in the following timeline") required participants to play the game and fill out missing information in a printed timeline of periods or remarkable events in the history of typography. The timeline already contained 11 items of information, but there were still five blanks to fill in (two major periods and three remarkable events of historical typography). The *nonspecific goal instruction* ("Work on the following game-based course so that you can tell other people about the birth and development of typology") encouraged participants to play the game, explore the history of typography, and learn as much as they could.

After reading one of these two instructions, players clicked on a start button and were automatically redirected in Type:rider. Throughout the duration of the game, the screen was recorded using BB FlashBack software, in order to collect consultation times and activities.

2.2.2. Measurements

In the first phase of the experiment, we administered a *prior knowledge* questionnaire containing 10 questions on typography (e.g., "What is a glyph?", "What is a calculis?"). These questions addressed different topics from those tackled in the present study.

Immediately after consulting Type:rider, players completed a *flow questionnaire* developed by Engeser and Rheinberg (2008) containing 10 items (e.g., "I had no difficulty concentrating", "I didn’t notice the time passing"). These items were rated on a Likert-like scale ranging from 1 (*Not at all*) to 7 (*Very much*).

We also evaluated *learning performances* after the game, using a questionnaire containing open-ended questions: eight paraphrase questions assessing the memorization of information provided during the videogame (e.g., "What is a scriptorium?"); and eight inference questions assessing the comprehension (i.e., quality of the mental model built with deep processing) of information provided in the videogame (e.g., "What is the oldest writing system still in use today?"). None of the answers to the inference questions were explicitly provided in Type:rider. Responses to each question were scored 0 point, 0.5 point, or 1 point. The scoring grid, constructed before the session, indicated the correct score to be assigned to each response, according to its degree of accuracy. Participants could score up to 8 points on paraphrase questions and 8 points on inference questions. To help the reader, inference questions are referred to hereafter as *comprehension questions*, and paraphrase questions as *memorization questions*.

Using BB FlashBack software, we collected information about the reading strategies implemented by players in the specific goal and nonspecific goal groups. During the experiment, we chose to focus on two indicators: number of scrollbacks and mean consultation time per page. We assumed that the number of scrollbacks inside the virtual book would tell us about how players scanned the instructional content to find relevant information. Regarding the amount of time spent consulting the instructional content, we divided the total content consultation time by the number of pages consulted for more than 3 seconds, to obtain the mean time per page consulted. We assumed that this variable would be more representative for our analysis because it would avoid situations where the content consultation time concerned only a few pages.

The game sequences, texts, illustrations and questionnaires were exactly the same for all the participants.

2.3 Procedure

The experiment took place in a room divided into two booths, each containing a computer. Participants were randomly assigned to one of the two conditions.

In the first experimental phase (pretest), participants had to fill in an information form collecting information about their age, sex, university course and level. They also completed the 10-item prior knowledge questionnaire

In the second experimental phase, the experimenter launched the screen recorder. Participants were equipped with a headset and invited to watch a slideshow informing them that they would have to complete two chapters ("Origins" and "Gothic") of a videogame named Type:rider. They also received either a specific or a non-specific goal instruction. Participants in the specific goal condition were given a printed timeline with five blanks to fill in during the session. After they had read their instruction, participants had to click on the start button to be automatically redirected to Type:rider. When participants reached the end of the second ("Gothic") chapter, the videogame and screen recorder were turned off by the experimenter. On average, participants spent 27 minutes on the game and the total mean time spent on the pages during the game was 12 minutes.

In the third experimental phase, participants filled in the flow questionnaire, followed by the learning performances questionnaire. At the end of the session, they were asked to recognize the instruction they had been given. The total duration of the whole experiment was 1 hour.

3 Results

3.1 Descriptive statistics

Table 1 shows the mean scores and standard deviations for the specific instruction and nonspecific instruction groups on the study variables.

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Table 1

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3.2 Preliminary analysis

We ran a preliminary analysis to test the psychometric properties of our measures, namely the reliability of the learning performances and flow questionnaires, and the validity of the constructs used in our study.

- ***Reliability of questionnaires***

As shown in Table 1, the memorization and comprehension items seemed to have a limited discriminatory power (i.e., floor effect) that may have compromised reliability. We found a Cronbach's alpha of 0.39 for comprehension items, and a Cronbach's alpha of 0.41 for memorization items. This point is further addressed in the Discussion. We also found a Cronbach's alpha of 0.80 for the flow questionnaire, showing that the items were homogenous.

- ***Validity of constructs***

Table 2 shows the validity of the constructs used in this study.

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Table 2

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As expected, given that they reflected two aspects of learning performances, comprehension and memorization scores were correlated ($r = .373$, $p < .001$). Correlations between these two variables and scores on the prior knowledge questionnaire were not significant. This questionnaire showed that none of the participants knew anything about the history of typography (see Table 1), and owing to this lack of variance, correlations with learning outcomes were nonsignificant (memorization scores: $r = .098$, $p = .357$; comprehension scores: $r = .004$, $p = .966$).

Table 2 also shows that there was no significant correlation between consultation time per page and number of scrollbacks ($r = .089$, $p = .404$). Consultation time per page was tested in an exploratory approach (see Hypothesis 3b), and the number of scrollbacks was not the only behavioral variable that could influence consultation time. This point is addressed further in the Discussion.

3.3 Prior knowledge test

For the prior knowledge test on the history of typography, Levene's homoscedasticity test showed that the pretest variances were equal, $F < 1$. An analysis of variance (ANOVA) revealed that there was no significant difference between the specific goal ($M = 0.28$, $SD = 0.41$) and nonspecific goal ($M = 0.23$, $SD = 0.36$) groups on prior knowledge, $F < 1$ (see Table 1).

3.4 Main effect of goal specificity on learning outcomes: memorization (H1), comprehension (H2) and reading strategies (H3a & H3b)

We tested the effect of goal specificity on learning performances and reading strategies. Table 1 shows the mean scores and standard deviations for the specific instruction and nonspecific instruction groups on the memorization and comprehension questions.

- ***Learning performances***

We first performed a multivariate analysis of variance (MANOVA), which showed that goal specificity affected learning performances at a trend level, $F(2, 88) = 2.75$, $p = .07$, $\eta^2 = .06$.

- *Memorization*

To test H1, we began by running Levene's homoscedasticity test, which revealed a nonsignificant result for the memorization items ($F < 1$). An ANOVA showed that goal specificity had no significant effect on memorization scores, $F(1, 89) = 1.42$, $MSE = 0.88$, $p = .331$, $\eta^2 = .02$. Our first hypothesis was therefore not supported, as no effect of goal specificity on memorization was observed.

- *Comprehension*

To test H2, we first ran Levene's homoscedasticity test to check that the variances were equal for the comprehension items, $F(1, 89) = 1.02$, $p = 0.314$. An ANOVA conducted on comprehension scores demonstrated that learners in the specific goal condition ($M = 1.19$, $SD = 0.90$) performed more poorly than learners in the nonspecific goal condition ($M = 1.69$, $SD = 1.12$), $F(1, 89) = 5.41$, $MSE = 1.04$, $p = .022$, $\eta^2 = .06$. Our second hypothesis was thus supported, as the nonspecific goal instruction resulted in better comprehension than the specific goal instruction did.

- ***Reading strategies***

For H3a, we looked at the number of times participants scrolled back during the navigation. Table 1 shows the mean numbers of scrollbacks and standard deviations for the specific instruction and nonspecific instruction groups, and includes the mean consultation time per page and standard deviations for the specific goal and nonspecific goal groups.

First, we ran Levene's test to check the homoscedasticity of the variable number of scrollbacks while reading the instructional content, $F(1, 89) = 3.66$, $p = .059$. An AVOVA revealed that participants in the specific goal condition ($M = 2.04$, $SD = 2.09$) made more scrollbacks than participants in the nonspecific goal condition (*M* = 0.98, *SD* = 1.42), $F(1, 89) = 8.19$, $MSE = 25.86$, $p = .005$, $\eta^2 = .08$.

H3b concerned the effect of goal specificity on mean consultation time per page. We ran Levene's test to check the homogeneity of variances for this variable, $F(1, 89) = 0.29$, $p = .59$. There was no effect of goal specificity on mean consultation time per page, $F(1, 89) = 1.27$, $p = .263$.

To sum up, H3a concerning the scrollback variable was validated, as the group with the specific instruction scrolled back more than the group with the nonspecific instruction did, possibly reflecting a means-ends analysis. Our exploratory analysis testing H3b showed that there was no goal specificity effect on mean consultation time per page.

3.5 Influence of flow experience on learning performances (H4)

We ran two analyses of covariance (ANCOVAs) to test H4. This approach enabled us to control for the effect of goal specificity in order to ascertain whether the level of flow experience influenced memorization and comprehension.

- ***Memorization***

We began by running Levene's test to check that the variances of the memorization scores were equal, $F(1, 89) = 1.20$, $p = .276$. The first ANCOVA showed that flow experience had a positive influence on memorization scores, $F(1, 88) = 6.04$, $MSE = 0.83$, $p = .016$, $\eta^2 = .06$.

- ***Comprehension***

Levene's test indicated that the variances of comprehension scores were not heterogeneous, $F(1, 89) = 0.48$, $p = .490$. As expected, the second ANCOVA showed that comprehension scores were positively predicted by flow level, $F(1, 88) = 5.38$, $MSE = 0.99$, $p = .023$, $\eta^2 = .06$.

Finally, Hypothesis 4 was entirely confirmed. As expected, flow experience positively influenced memorization and comprehension performances.

3.6 Main effect of goal specificity on flow experience (H5a), and mediation by flow of relationship between goal specificity and learning performances (H5b)

H5a, concerning the effect of goal instruction on the level of flow experience, was also tested with an ANOVA. Table 1 shows the mean flow ratings and standard deviations for the specific and nonspecific goal groups.

Levene's homoscedasticity test showed that the variances of the flow score, $F(1, 89) = 1.73$, $p = .192$, did not differ. Our data revealed that there was no significant difference in levels of flow experience between the specific goal ($M = 50.11$, $SD = 10.49$) and nonspecific goal ($M = 50.95$, $SD = 8.19$), $F < 1$, groups. Contrary to our expectations, goal specificity had no significant effect on flow experience. This result led us to reject H5b, as the conditions required for our mediation analysis were not met.

3.7 Summary of the main results

Some, but not all, of our hypotheses were confirmed. In the first part of our analysis, we rejected H1, as we failed to demonstrate a goal specificity effect on memorization scores. By contrast, the nonspecific goal enhanced comprehension scores, compared with the specific goal, thus supporting H2. Some support was also found for H3a, as the nonspecific goal generated fewer scrollbacks than the specific goal. Concerning the exploratory analysis included in H3b, we found that goal specificity had no significant influence on mean consultation time per page.

In the second part of our analysis, we observed a beneficial influence of flow on both memorization and comprehension, fully supporting H4. However, there was no support for H5a, concerning the effect of goal specificity on flow experience, meaning that we could not test H5b concerning the possible mediating role of flow.

4 Discussion

The first purpose of the present study was to examine the goal-specificity effect on learning outcomes in an ECG. Taken together, our results demonstrated that the nonspecific goal instruction improved learning outcomes, compared with the specific goal condition. The nonspecific condition brought benefits in terms of comprehension, but not memorization.

This positive goal-specificity effect on comprehension was in line with the literature. More specifically, it confirmed Miller et al. (1999)'s findings that an ECG instruction featuring a nonspecific goal increases learning performances compared with an instruction featuring a specific goal. Drawing on the dual space and cognitive load explanations, we postulated that a specific goal condition triggers a detrimental strategy that strains working memory capacity. Learners who were given a specific goal tended to work in the instance space, using a pure problem-solving strategy (i.e., *means-ends analysis*) to fill in the timeline. Given the number of elements that had to be considered at the same time, this detrimental strategy strained working memory capacity and meant that the content was simply scanned. This surface processing could explain the impaired performance on comprehension questions. By contrast, learners who were given a nonspecific goal were encouraged to work in the rule space, triggering a learning strategy. This strategy, consisting in creating and testing hypotheses, was fully compatible with meaningful processing and seems to have accounted for the enhanced performances on the comprehension questions.

The fact that there were more scrollbacks with the specific goal, compared with the nonspecific one, would appear to confirm that the instructional content was *scanned* (i.e., means-ends analysis) by learners in this group. Some studies have already tried to assess this kind of extraneous processing with subjective cognitive load measures (Nebel, et al., 2016; Künsting et al., 2011; Wirth et al., 2009). In line with these studies, we suggest that some more specific measures of extraneous cognitive load (i.e., Kalyuga, Chandler, & Sweller, 1998) should be included in future studies, in order to gain a better understanding of how extraneous processing affects learning outcomes. In addition, the use of eye tracking could shed light on scanning activities in the specific goal condition.

While our results confirm Miller et al. (1999)'s finding of a higher level of learning performance with a non-specific goal, they are not in accordance with Nebel et al. (2016). This difference with our results probably originates in the game used in their experiment. Nebel and colleagues (2016) chose a sandbox game in which players are allowed to roam and to select their own task, whereas like Miller and colleagues (1999), we based our study on a progression-style game in which the player is guided. Further research should evaluate the effect of goal-oriented instruction in games fostering pure discovery learning (i.e. sandbox) in contrast with guided discovery learning (i.e. progression-style game).

Turning to the comparison between the specific and nonspecific goals, there is strong evidence in the literature of the goal-specificity effect (e.g., Miller et al., 1999; Sweller et al., 2011; Vollmeyer & Burns, 2002; Ward & Sweller, 1990). A few years ago, some authors started to argue that the differences between specific and nonspecific goals are probably more complex than they appear. According to Wirth et al. (2009), either a specific or a nonspecific goal may be pursued when the task features a learning goal or a problem-solving goal. *Learning goals* can be described as more or less well defined internal mental states of the learner's knowledge, and learning relies on schema acquisition and/or rule induction to bring about fundamental changes in cognitive representations. In the context of instructional design, this type of goal is more desirable than *problem-solving goals*. The latter are more or less well-defined states of the learner's external environment, and solving the problem requires changes to specific aspects of that environment (Sweller & Levine, 1982; Wirth et al., 2009). In our study, both instructions were designed to motivate schema acquisition, but filling in a timeline may also, to a certain extent, have encouraged learners to pursue a problem-solving goal, in that they had to modify an external element of the learning environment. Drawing inspiration from Wirth et al. (2009), an appropriate means of avoiding this problem would have been to ask the learners to retain a particular item of information, in order to ensure that specific and nonspecific goals were compared using a learning goal. However, this solution has two major drawbacks: 1) maintaining a particular item in working memory competes with other cognitive processes, meaning that it ceases to be a pure comparison of goal specificity; and 2) finding the item does not prevent learners from using a nonspecific problem-solving strategy. In this experiment, we considered that filling in a timeline was a good compromise, but we acknowledge that further studies are needed to see how a learning goal can be used to achieve better control over goal specificity.

The second purpose of our study was to explore the relationship between goal specificity, flow experience, and learning outcomes. One of the first questions it should raise is why assess flow experience? *Flow* corresponds to an immediate optimal experience. It is intrinsically rewarding, and the urge to replicate it can drive engagement in a learning game. In many studies, flow is confused with intrinsic motivation, which is conceptualized as the ultimate reason for achieving a behavior through self-determination. In line with Eccles and Wigfield (2002), we assumed that these are actually two different constructs, leading to two different forms of engagement in an activity. In our study, we asserted that flow experience is a more accurate measure of motivation in ECGs and should open up some interesting research avenues. However, choosing to assess flow experience does not mean that intrinsic motivation is an irrelevant variable. As mentioned by Eccles and Wigfield (2002), learners may have several reasons for engaging in a learning task, including the pursuit of an immediate optimal experience and learning a specific content with a more or less internalized regulation. Our view is that further studies should assess the impact of both these reasons for engagement, in order to gain a more accurate understanding of their specific influence on learning outcomes.

As expected, we demonstrated that flow experience positively influences memorization and comprehension. This finding is in line with Admiraal et al. (2011), Hamari et al. (2016) and above all Hou (2015), who demonstrated that a high level of flow triggers a deeper reflective process. Experiencing an intense state of concentration and a high level of cognitive absorption seems to encourage learners to process educational content more deeply. In other words, individuals working in flow seem more eager to achieve meaningful learning, which may explain the positive influence of flow on memorization and comprehension. Few contributions have so far explored the promising benefits of flow experience in instructional design. Our observations are fundamental for two reasons: they show how flow experience can be measured in digital game-based learning, and raise many questions about its powerful implications for ECG learning performances.

Coming back to the question of the relationship between goal specificity, flow, and learning outcomes, we observed that, contrary to our expectations, the nonspecific goal condition did not trigger more flow during learning. This result is in contradiction with Schweickle et al. (2017), who found that a nonspecific goal in a cognitive task elicited more flow experience than a specific goal did. A closer look at our data strikingly reveals that the level of flow was moderately high in both conditions (mean rating 50/70 for both). There are two plausible explanations for this result: either filling in the timeline in the specific goal condition did not impair the flow experience, or it elicited some flow by providing the right level of challenge with respect to the learners' skills. Further studies are needed to understand the relationship between the goal specificity effect and flow experience. This nonsignificant effect meant we could not test whether flow mediated the effect of goal specificity on learning performances. We can nevertheless assume that considering motivational investment as a mediator between the quality of game features and learning outcomes is a fruitful avenue of research.

The present results raise several possibilities for future research. The first aspect that should be considered in the future is related to the choice of wording in the nonspecific goal instruction. We based our instruction on Vollmeyer and Burns (2002)'s nonspecific goal instruction, which uses the words "so that you can tell other people". It could be that this particular wording also triggers deeper cognitive processing, similar to the self-explanation effect (Johnson & Mayer, 2010), whereby some learners achieve higher learning performances when they are regularly urged to explain their own responses. Our experimental design was different, as our participants did not receive these regular prompts to explain their own responses, but further studies should be wary of the impact of this nonspecific wording on cognitive processing. Second, one limitation of the current study was the low discriminatory power of the memorization and comprehension items.

The low memorization and comprehension scores suggest a floor effect, caused by the items' high level of difficulty. This low discriminatory power may have entailed a problem of reliability, as indicated by the low Cronbach's alphas for both measures (comprehension questions: $\alpha = 0.39$; memorization questions: $\alpha = 0.41$). However, this low reliability was not a problem in our particular case, as our analyses involved comparing the means of the two conditions. Low reliability increases random measurement error, which decreases statistical power but does not bias group averages. In the present case, low reliability did not prevent us from observing significant differences between the two groups, and the significant correlation between the memorization and comprehension measures ($r = .373$, $p < .001$) confirms that they captured a proportion of true variance. This correlation shows that despite our floor effect problem and its effect in terms of reliability, our memorization and comprehension items did actually assess learning performances. Further studies should nonetheless limit the difficulty of learning items in order to increase the discriminatory power and reliability of these measures.

A third possible extension of this work would be to improve on the measurement of reading strategy. We studied the time per page variable in an exploratory approach, as this variable could reflect two opposite behaviors: *scanning*, resulting in less consultation time per page; or *scrolling back*, increasing the consultation time per page (see H3b). Our results did not allow us to adjudicate between these two possibilities. We expected that the scrollback and time per page variables in our correlation table would shed light on participants' reading strategies, but there were no significant correlations.

In this context, it is questionable whether the time per page variable provided accurate information about reading strategies. We suggest that this indicator offered too general a view of reading behaviors. For example, scrollback strategies can be used conjointly with other behaviors such as reading a word or sentence several times, but also scanning the next paragraph quickly if it is perceived to be less interesting. As a consequence, consultation time per page may be influenced by all these behaviors. Future studies should include the use of an eyetracking method to gain some more accurate measures of page exploration.

A fourth possible extension of this study would be to consider other variables that may mediate or moderate the observed effect of goal instructions on learning. In particular, we believe that the achievement goals pursued by learners (Harackiewicz et al., 2000), as well as their interest in the task (Alexander & Murphy, 1998), may affect the observed results on goal specifity and flow. With the current results indicating that flow does not play a mediating role, further studies should examine the possibilities offered by these other variables.

5. Conclusion

The present study opens up several new avenues for research. It suggests that the nature of the instructions provided in ECGs can substantially affect the nature of the cognitive processes that take place during learning. ECG design teams should pay attention to the type of instructions provided to the learners, and more precisely to the goals that are induced during digital game-based learning.

This study also raises questions about the impact of flow experience on learning outcomes. One striking result is that flow positively affected learning performances. Up to now, flow and intrinsic motivation have often been confused, but a clear distinction should be made in future studies, in order to gain a better idea of their respective effects on learning.

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Appendices

[Insert appendices here]

Footnotes

[Insert footnotes here, do not use Word's footnoting function]

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Figure 1

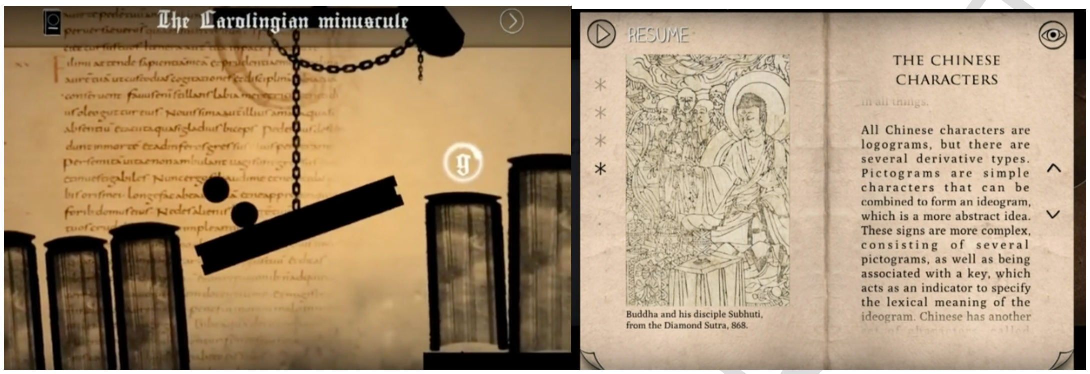

Figure 1: Screenshot of the Type:rider game, with examples of the platform game part (left) and the educational content part (right).

Highlights

- We explored the links between goal specificity, flow and learning outcomes in ECGs.
- A goal-specific effect was found for comprehension but not for memorization.
- A specific goal produced more scrolling back, a suboptimal reading strategy.
- Flow experience positively influenced memorization and comprehension.

Table [Insert table number here]

Table 1:

Descriptive statistics including Mean Scores and Standard Deviations for our dependent variables

	Specific goal instruction (*n* = 44)		Non-specific goal instruction (*n* = 47)	
	M	*SD*	*M*	*SD*
Prior knowledge (Max. Score 10)	0.28	0.41	0.23	0.36
Memorization questions (Max. Score 8)	1.16	0.89	1.39	0.98
Comprehension questions* (Max. Score 8)	1.19	0.88	1.69	1.12
Scrollbacks *	2.04	2.09	0.98	1.42
Mean time per page	83.94	33.33	76.22	32.12
Flow experience (Max.70)	50.11	10.49	50.95	8.19

Note. * $p < .05$., ** $p < .01$

Table 2:

Summary of intercorrelations between the dependent variable Pre-test, Paraphrases, Inferences, Scrollbacks, Time/page, Flow.

	Pre-test	Memorization	Comprehension	Scrollbacks	Time/page	Flow
Pre-test	1					
Memorization	.098	1				
Comprehension	.004	.373**	1			
Scrollbacks	.171	.207*	.019	1		
Time/page	-.115	.123	.118	.089	1	
Flow	.164	.257*	.243*	.213*	-.105	1

Note. * $p < .05$., ** $p < .01$