Computers in Human Behavior 70 (2017) 197–206

Contents lists available at ScienceDirect

Computers in Human Behavior

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

Full length article

Assessing fraction knowledge by a digital game

Manuel Ninaus [a, b, *], Kristian Kiili [c], Jake McMullen [d], Korbinian Moeller [a, b, e]

[a] Leibniz-Institut für Wissensmedien, Tuebingen, Germany
[b] LEAD Graduate School, Eberhard-Karls University Tuebingen, Germany
[c] TUT Game Lab, Tampere University of Technology, Pori, Finland
[d] Centre for Learning Research, University of Turku, Turku, Finland
[e] Department of Psychology, Eberhard Karls University, Tuebingen, Germany

A R T I C L E I N F O

Article history:
Received 2 September 2016
Received in revised form
30 December 2016
Accepted 1 January 2017
Available online 4 January 2017

Keywords:
Digital game
Alternative assessment
Mathematics
Fractions
Serious game

A B S T R A C T

Serious or educational games gain increasing research interest as tools to augment traditional instructional approaches on scholastic learning, especially in mathematics education. In this study, we investigated whether game-based approaches may not only be useful to foster numerical learning but may also be valid as an assessment tool. To measure their conceptual knowledge of fractions eleven-year-old students played a math game on tablet computers using tilt-control to navigate an avatar along a number line for a total of 30 min. Findings indicated that hallmark effects of fraction magnitude processing typically observed in basic research, such as the numerical distance effect, were successfully replicated using the game-based assessment. Moreover, fraction comparison performance as well as fraction estimation accuracy correlated significantly with students' math grades. Therefore, the results of the current study suggest that game-based learning environments for fraction education (even using tilt-control) may also allow for a valid assessment of students' fraction knowledge.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Fractions are commonly considered as one of the most difficult relations to learn and even adults frequently fail to process them correctly (Gigerenzer, 2002; Siegler, Fazio, Bailey, & Zhou, 2013 for a review). Fraction understanding, however, seems crucial for math education (e.g. Booth & Newton, 2012). Not only that high school students' fraction knowledge correlates very highly with their actual mathematics achievement (up to $r = 0.8$), fifth graders' fraction knowledge also predicts future algebra and overall mathematics achievement in high school (e.g., Bailey, Hoard, Nugent, & Geary, 2012; Booth & Newton, 2012). Given the widespread difficulties many adults and children face with reasoning about fractions, traditional instructional methods may be reconsidered and complemented by new tools for fostering fraction knowledge. This seems specifically important because deficient numeracy skills are detrimental to individuals' job and life prospects (Parsons & Bynner, 2006).

Serious games or game-based applications have the potential to provide such new, engaging, and innovative ways of training children as well as adults in mathematics. Recently, the use of such games in cognitive training, learning and educational interventions increased considerably (for a systematic review see Boyle et al., 2016). Studies indicate that the use of game-based tasks can not only increase motivation and engagement of users but also their performance (e.g. Mekler, Brühlmann, Opwis, & Tuch, 2013; Ninaus et al., 2015; for a review see; Lumsden, Edwards, Lawrence, Coyle, & Munafò, 2016). Thus, in this study we used our game-based rational number research engine "Semideus" to tackle one of the major hurdles in mathematics education – students' fraction knowledge.

1.1. Number line estimation task and fractions

The processing and learning of fractions is one of the most challenging problems in mathematics education (National Mathematics Advisory Panel, 2008). A crucial part of fraction understanding and processing is the successful representation of fraction magnitude (reflecting the relation between denominator and numerator) and carrying out arithmetic operations on them. The concept of a mental number line is an often used metaphor to describe our mental representation of number magnitude. Accordingly, the number line estimation task, in which participants

* Corresponding author. Leibniz-Institut für Wissensmedien, Schleichstr. 6, 72076 Tuebingen, Germany.
E-mail address: m.ninaus@iwm-tuebingen.de (M. Ninaus).

http://dx.doi.org/10.1016/j.chb.2017.01.004
0747-5632/© 2017 Elsevier Ltd. All rights reserved.

have to indicate the spatial position of a target number on a number line with only its start and endpoint specified (e.g., where goes 42 on a number line ranging from 0 to 100), is an often used approach to measure and train individuals' representation of number magnitude (e.g., Link, Moeller, Huber, Fischer, & Nuerk, 2013; Siegler & Opfer, 2003). Importantly, performance in the number line estimation task is associated with actual mathematical performance and can predict future mathematical achievement (e.g., Booth & Siegler, 2006). Therefore, recent research studies emphasized that children's mental representation of number magnitude can be fostered by training to map numbers (including fractions) onto space as in the number line estimation task (e.g. M. Schneider & Stern, 2010; Siegler & Ramani, 2008). Most of the time conventional computer tasks or paper-pencil versions are used to train and assess individuals' representation of number magnitude. However, in recent years new and innovative methods of training numerical skills were developed such as trainings with dance mats (Fischer, Dackermann, Cress, Nuerk, & Moeller, 2014), interactive whiteboards (Fischer, Moeller, Huber, Cress, & Nuerk, 2015), as well as game-like versions of the number line task (e.g. Kucian et al., 2011).

According to conceptual change theories, children form an initial conception of numbers as counting units before they encounter fractions, and later they draw heavily on this initial understanding to make sense of rational numbers (DeWolf & Vosniadou, 2015; Stafylidou & Vosniadou, 2004). As such, misconceptions and biases about rational numbers tend to originate in children's erroneous belief that properties of whole numbers can be applied to rational numbers. According to DeWolf and Vosniadou (2015) this is detrimental for children's understanding of fractions as it implies that they tend to treat denominators and numerators as two separate whole numbers instead of considering their relation to each other. From this conceptualization they often infer that the value of a fraction increases when either the denominator or the numerator increases. For example, 2/5 (0.4) is larger than 3/8 (0.375) although its numerator 2 is smaller than 3 and the denominator 5 is smaller than 8. This phenomenon is referred as a *whole number bias* (Ni & Zhou, 2005) or *natural number bias* (Alibali & Sidney, 2015).

The whole number bias has been found to cause difficulties in reasoning about the magnitude of fractions (e.g. Van Hoof, Lijnen, Verschaffel, & Van Dooren, 2013). Interestingly, even mathematics experts and educated adults have been shown to be slower to respond on tasks in which whole number features are incongruent with rational number features (Obersteiner, Van Dooren, Van Hoof, & Verschaffel, 2013; Vamvakoussi, Van Dooren, & Verschaffel, 2012). Importantly, however, successful understanding of the magnitude of fractions was found to be an important precursor of later knowledge of rational numbers, such as the density of rational numbers (McMullen, Laakkonen, Hannula-Sormunen, & Lehtinen, 2014) and arithmetic operations with rational numbers (Van Hoof, Vandewalle, Verschaffel, & Van Dooren, 2015).

Other problems and misconceptions with fraction magnitude processing are of interest in examining how a digital game can assess students' conceptual knowledge of the numerical magnitude of fractions. Correct representation of fraction magnitude as the relation between denominator and numerator can be conceptualized as and assessed by being able to localize the magnitude of a fraction on a number line estimation task for the number range 0–1. Applying such fraction knowledge in a magnitude comparison task (e.g. which one of the numbers is larger: 3/8 or 4/5) would allow for further information on the representation of fraction magnitude. From basic research it is known that the so-called *distance effect* (i.e., longer and more error prone comparisons of fractions that are closer in magnitude than for fractions further apart in magnitude) indicates a successful representation of fraction magnitude (e.g., M. Schneider & Siegler, 2010).

1.2. Present study

The present study is a part of an ongoing research project in which we are developing a game-based rational number research engine called Semideus. The game is based on recent findings on fraction processing and numerical development (e.g. McMullen et al., 2014; Siegler, Thompson, & Schneider, 2011; Vamvakoussi, 2015) and theories that provide an account for the use of manipulatives in digital learning materials (Pouw, van Gog, & Paas, 2014). We implemented the assessment of children's conceptual fraction knowledge directly into the gameplay. In particular, students had to indicate the magnitude of a fraction as an analogue quantity by locating its position on a number line and to compare the magnitudes of two fractions by arranging them according to their magnitude on the number line. For the latter magnitude comparison task we were interested in replicate whole number bias and numerical distance effect in the current game. Furthermore, considering math grades as an external criterion allowed us to validate our game-based approach for assessing conceptual fraction knowledge.

The main purpose of the current study was to demonstrate the applicability of our game-based rational number research engine Semideus to assess fraction knowledge. More specifically, we investigated advantages and disadvantages of using a game as a research and assessment tool for investigating young students' biases in fraction processing and identifying factors from playing behaviour that may be used to define more exhaustive learning analytics for fraction knowledge.

In order to successfully apply the Semideus research engine for future research studies, one needs to demonstrate that our game-based approach provides similar effects (e.g. whole number bias, distance effect; see also 1.1) as reported with conventional (e.g. paper-pencil) and non-game-based assessment measures. Thus, in the current study we investigated 5th graders' performance of comparison and estimation of fraction magnitudes while playing the Semideus Exam game on a tablet with tilt control.

First, a general demonstration of participants' ability to master the user interface (including tilt-control) within the first few trials of assessment is necessary before any form of assessment can be performed. Following this, we assume that students' performance on the game will be defined by their understanding of fraction magnitude and not driven by general game mechanics. In order to evaluate this statement we set up six hypotheses that direct this study. All the hypotheses are deduced from previous research on numerical cognition and thus this approach provides important information about the applicability and usefulness of the Semideus game as an assessment and research tool.

Overall, whole number comparisons tasks should be relatively trivial at this age. Thus, we expected that children should perform worse in comparisons of fraction magnitudes (*Hypothesis 1*) than in comparisons of whole number magnitudes (DeWolf & Vosniadou, 2015; M.; Schneider & Siegler, 2010). Second, however, we expected that there will be a positive relation between students' whole number comparison speed and their fraction comparison speed (*Hypothesis 2*), as would be expected by the integrative theory of numerical development (e.g. Siegler et al., 2011).

Previous research has shown that fractions that are consistent with whole number ordering are mastered better than fractions that are inconsistent with whole number ordering due to the whole number bias (Vamvakoussi et al., 2012; Van Hoof et al., 2015). Therefore, we expect that students ability to solve consistent items is better (*Hypothesis 3a*) and faster (*Hypothesis 3b*) than for

Download English Version:

https://daneshyari.com/en/article/4937291

Download Persian Version:

https://daneshyari.com/article/4937291

Daneshyari.com