Learning and Individual Differences 37 (2015) 107–117

Contents lists available at ScienceDirect

Learning and Individual Differences

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

Third graders' verbal reports of multiplication strategy use: How valid are they?

Helen C. Reed [a,*], Claire Stevenson [a,1], Marije Broens-Paffen [a,2], Paul A. Kirschner [b], Jelle Jolles [a]

[a] Department of Educational Neuroscience and LEARN! research institute for learning and education, Faculty of Psychology and Education, VU University Amsterdam, Van der Boechorststraat 1, 1081 BT Amsterdam, The Netherlands
[b] Welten Institute, Research Centre for Learning, Teaching and Technology, Open University of the Netherlands, P.O. Box 2960, 6401 DL Heerlen, The Netherlands

ARTICLE INFO

Article history:
Received 8 January 2014
Received in revised form 20 September 2014
Accepted 7 November 2014
Available online xxxx

Keywords:
Verbal reports
Multiplication strategies
Multiplication performance
Problem characteristics
Cognitive characteristics

ABSTRACT

This study investigates whether children's verbal reports accurately represent their thinking processes when solving simple multiplication problems. A total of 106 third graders in Dutch mainstream primary schools solved simple multiplication problems and retrospectively reported how they had done this. The degree to which verbal reports predict children's problem-solving performance in ways that correspond to known patterns of response latency, accuracy, errors and strategy choice was assessed. The analyses took account of relevant problem characteristics and child cognitive characteristics (i.e., math ability, verbal ability, phonological decoding speed) known to affect the relation between strategy use and multiplication performance. The verbal reports were largely consistent with known patterns, supporting the use of verbal reports in assessing multiplication strategy use. Moreover, verbal reports provide valuable information that can alert teachers and educational researchers to specific issues that students face when solving simple multiplication problems. Considerations for soliciting reliable verbal reports are suggested.

1. Introduction

It is well established that children use a variety of strategies to solve arithmetic problems. Common strategies involve *counting*, *repeated addition* (e.g., $4 \times 3 = 3 + 3 + 3 + 3 = 12$), using *derived facts* (also known as decomposition or transformation, e.g., $3 + 4 = 3 + 3 + 1 = 7$; $3 \times 6 = 3 \times 5 + 3$) and *direct retrieval* of facts from memory (Imbo & Vandierendonck, 2008a,b; Lemaire & Siegler, 1995; Mabbott & Bisanz, 2003; Sherin & Fuson, 2005; Siegler, 1987, 1988; Siegler & Shipley, 1995).

Children show great variability in thinking and may at any one time use different strategies in different circumstances, depending on their age, problem difficulty, their degree of experience with the type of problem, their degree of confidence in the solution, strategy characteristics, and individual differences such as gender, achievement level and working memory capacity (Foxman & Beishuizen, 2002; Imbo & Vandierendonck, 2008a,b; Lemaire & Siegler, 1995; Mabbott & Bisanz, 2003; Siegler, 1988; Siegler & Shipley, 1995; Timmermans, Van Lieshout, & Verhoeven, 2007; Verschaffel, Luwel, Torbeyns, & Van Dooren, 2009). Typically developing children progress from relying on procedural strategies such as counting and addition to increasingly frequent use of more mature memory-based strategies, particularly direct retrieval (Geary, 2004; Lemaire & Siegler, 1995). Low math performers, however, exhibit developmental delay in their patterns of strategy use and may have long-lasting difficulties in using memory-based retrieval strategies (Geary, 2004; Geary, Hoard, Nugent, & Bailey, 2012; Jordan, Hanich, & Kaplan, 2003). Reciprocally, arithmetic performance appears to depend on strategy use, with increased use of the fastest and most accurate strategy (i.e., direct retrieval) producing faster and more accurate performance (Geary, 2004; Lemaire & Siegler, 1995).

Clearly, children should be helped to progress from using time-consuming and error-sensitive procedural methods to using more mature retrieval strategies. Such progression does not necessarily occur – even with typically developing children – when these strategies are not given explicit attention in school (Steel & Funnell, 2001). This issue is particularly relevant for low math performers, for whom progression is often delayed (Geary et al., 2012; Jordan et al., 2003). The performance disadvantage of these children may be compounded when immature strategy use appropriates cognitive resources – most importantly working memory – resulting in a reduced capacity to process higher-level aspects of mathematical learning (Raghubar, Barnes, & Hecht, 2010).

An important issue for educational practice is to determine which problem-solving strategies a child is currently using. If children who

* Corresponding author. Tel.: +31 20 598 7023; fax: +31 20 598 8902.
E-mail addresses: HC.Reed@vu.nl (H.C. Reed), cstevenson@fsw.leidenuniv.nl (C. Stevenson), Marije.Broens@ou.nl (M. Broens-Paffen), Paul.Kirschner@ou.nl (P.A. Kirschner), J.Jolles@vu.nl (J. Jolles).
[1] Present address: Faculty of Social and Behavioural Sciences, Leiden University, P.O. Box 9555, 2300 RB Leiden, The Netherlands.
[2] Present address: Faculty of Psychology and Educational Sciences, Open University of the Netherlands, P.O. Box 2960, 6401 DL Heerlen, The Netherlands.

http://dx.doi.org/10.1016/j.lindif.2014.11.010
1041-6080/

consistently use more immature strategies than their peers can be readily identified in the classroom, teachers could take remedial action before more complex learning is compromised (Dowker, 2004; Gersten, Jordan, & Flojo, 2005). Importantly, teachers would then not have to wait for signs of failure to become established before referring children for specialised testing. A practicable and direct way for teachers to assess strategy use would be to ask children how they solve arithmetic problems. Yet, if this method is to be advocated, it is first necessary to establish whether what children report about how they have solved a problem accurately represents their thinking processes (i.e., veridicality). To that end, the goal of the present study is to investigate the veridicality of children's verbal reports of strategy use during simple multiplication problem-solving. Difficulties in multiplication learning are often reported by students and teachers (Kilpatrick, Swafford, & Findell, 2001; Steel & Funnell, 2001; Wallace & Gurganus, 2005), which makes it particularly relevant to investigate strategy use in this area.

1.1. Identifying strategy use through verbal reports

Verbal reports can be extremely valuable and may provide the most informative picture of cognitive processing in problem-solving (Fox, Ericsson, & Best, 2011; Robinson, 2001; Taylor & Dionne, 2000; Sherin & Fuson, 2005; Siegler, 1987, 1989). In one of the few extant studies to explicitly consider the validity of children's verbal reports of arithmetical processing, Robinson (2001) argued that verbal reports can provide unique and rich information on children's problem-solving strategies that can help to build and test more complete theories of cognitive development. Verbal reports can also help identify difficulties encountered during problem-solving and help determine ways to alleviate these difficulties. Moreover, verbal reports are highly suitable for investigating individual differences in arithmetic strategy use (e.g., Imbo & Vandierendonck, 2008a,b; Mabbott & Bisanz, 2003; Van der Ven, Boom, Kroesbergen, & Leseman, 2012). In this respect, verbal reports can be superior to other commonly used measures, namely latency and accuracy data. Several authors have demonstrated that using these data to infer strategy use can severely distort the picture of performance. For example, when latencies are aggregated across subjects, individual differences are obscured, and when latencies are aggregated across strategies, variability in strategy use and performance is masked (Cooney, Swanson, & Ladd, 1988; Siegler, 1987, 1989).

Verbal reports can provide accurate indications of mental processing under certain conditions. For assessing children's arithmetic problem-solving, a number of conditions should be met. First, the act of reporting should not change performance (so-called 'reactivity'). For example, when people 'think aloud' while performing a task, the drain on cognitive resources required for verbalisation of task-related processes can impair performance (Chin & Schooler, 2008; Robinson, 2001; Russo, Johnson, & Stephens, 1989). Second, as the time taken to execute the task is of interest, additional time-consuming processing (e.g., verbalisation) should not be undertaken concurrently (Ericsson & Simon, 1993; Russo et al., 1989). Third, when a task is carried out through automatic processing (e.g., direct retrieval), people may be unable to report their mental actions at the time (Kirk & Ashcraft, 2001; Taylor & Dionne, 2000) but may be able to do so retrospectively (Robinson, 2001). Taken together, it is likely that these conditions may best be approximated by soliciting verbal reports immediately after task completion. Retrospective reports are widely used in psychological research and appear to have good validity when tasks are of short duration and relevant task-specific processing traces are still available in short-term memory (Crutcher, 1994; Ericsson & Simon, 1993; Taylor & Dionne, 2000). Interestingly, there is neurophysiological evidence for the validity of retrospective reports in mental arithmetic with adults (Grabner et al., 2009; Grabner & De Smedt, 2011[3]).

[3] Although the authors call these reports concurrent, the procedure description makes clear that reports were obtained immediately after solving the problem.

Nonetheless, there are reasons to question whether verbal reports are a valid reflection of cognitive processing, particularly when children are the respondents. Verbal report depends on the ability to recognise and articulate thought processes, and individuals – especially children – vary widely in the degree to which they are able to do this. For example, Siegler and Stern (1998) found that 90% of second graders in their study were able to use a shortcut strategy on inversion problems some time before they were able to explicitly report using it. Alibali (1999) and Broaders, Cook, Mitchell, and Goldin-Meadow (2007) reported that many third and fourth graders demonstrate an understanding of strategies for solving mathematical equivalence problems that they are unable to verbalise. Even adults are often able to perform tasks without being able to articulate how they have done this, a phenomenon that is well known in sequence and second language learning (e.g., Neil & Higham, 2012; Sanchez, Gobel, & Reber, 2010; Williams, 2005).

Furthermore, retrospective reports in particular could be open to bias and fabrication (Ericsson & Simon, 1993; Russo et al., 1989; Taylor & Dionne, 2000). In this respect, children's retrospective reports of arithmetic strategy use may be inaccurate in several ways. Children may over-report strategies whose salience is high (Kirk & Ashcraft, 2001) due to a certain type of instruction given during interview or through emphasis being put on particular strategies in the classroom (Taylor & Dionne, 2000). In that case, children may believe that reporting how they solved a problem is a test of – and therefore should reproduce – what they are supposed to have learned. Also, children may be aware that they are not supposed to use more primitive strategies such as counting. They may therefore deliberately under-report use of these strategies in order to conform to what they believe to be socially desirable. Furthermore, if a solution strategy involves both faster (e.g., direct retrieval) and slower (e.g., calculation) processes, children may only report the slower and perhaps more easily verbalised process (Ericsson & Simon, 1993; Kirk & Ashcraft, 2001).

In summary, although retrospective reporting is a promising method for assessing children's arithmetic strategy use in the classroom from both a theoretical and a practical point of view, important questions remain to be answered as to its validity. Validity is called into question when some thoughts are not reported (i.e., errors of omission) or when thoughts that did not occur are reported (i.e., errors of commission) (Russo et al., 1989). To date, the evidence of validity when used with children is not conclusive: discrepancies have been found between children's retrospective reports and other measures using observational or chronometric data (e.g., Cooney & Ladd, 1992; Cooney et al., 1988; Siegler, 1987, 1989; but see Wu et al., 2008). Furthermore, retrospective reports may be biased or fabricated: children may be tempted – as an effect of salience or social desirability – to under-report or over-report the use of certain strategies. It is important to resolve this issue if retrospective reporting is to be used as an assessment method in the classroom. If children over-report the use of mature strategies and under-report the use of immature strategies, teachers will not be able to determine their actual level of expertise and identify those who really do lag behind their peers.

1.2. Strategy use and multiplication performance

Previous research investigating children's multiplication performance from the point of view of strategy use has produced several robust findings. Performance is reported to be faster and more accurate when children use retrieval compared to procedural strategies and, of the procedural strategies, use of derived facts is faster and more accurate than counting and addition (Lemaire & Siegler, 1995; Siegler, 1988; Siegler & Shipley, 1995; Steel & Funnell, 2001). Regarding types of errors made, these tend to be primarily multiplicand-related (i.e., multiples of one of the multiplicands, e.g., $8 \times 4 = 28$). To a lesser extent, 'close misses' (i.e., small errors within a distance of 10% from the correct answer, e.g., $8 \times 4 = 33$) occur on procedural strategies and