Learning and Individual Differences 33 (2014) 12–22

Contents lists available at ScienceDirect

Learning and Individual Differences

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

The role of working memory abilities in lecture note-taking☆

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ARTICLE INFO

Article history:
Received 3 October 2013
Received in revised form 25 March 2014
Accepted 11 May 2014

Keywords:
Note-taking
Working memory
Individual differences

ABSTRACT

The utility of lecture note-taking is well documented, with most studies dedicated to understanding how to maximize the benefits of note-taking. Far less attention has been focused on understanding the cognitive processes that underlie note-taking and how the benefits of note-taking vary with individual differences in the ability to carry out these processes. One cognitive ability that has been hypothesized to be important for note-taking is working memory: the ability to temporarily store and manipulate limited amounts of information. The current paper addresses why working memory is important for lecture note-taking and reviews studies that have examined the relationship between individual differences in working memory abilities and individual differences in note-taking. There is currently a lack of consensus regarding the nature of this relationship, and this review addresses possible reasons for what may appear to be inconsistent results, including differences in how working memory and its role in note-taking have been assessed, note-taking modality, and individual differences in note-taking strategy.

1. Introduction

The process of note-taking is familiar to just about everyone. Although note-taking occurs in both academic and non-academic contexts, the positive consequences of note-taking are most clearly evident in educational situations where students are evaluated on the basis of how much information they can retain from lectures. Indeed, note-taking has long been linked to positive test performance (e.g., Armbruster, 2009; Crawford, 1925). This relationship is not lost on students, who acknowledge lecture note-taking as a crucial component of the educational experience (Dunkel & Davy, 1989). In fact, lecturing constitutes more than 80% of college instructors' teaching methods (Wirt et al., 2001), and therefore it should not be surprising that nearly all college students take notes in class (Palmatier & Bennett, 1974; Van Meter, Yokoi, & Pressley, 1994), even when they are not explicitly told to do so by the instructor (Williams & Eggert, 2002).

2. A brief overview of lecture note-taking research

DiVesta and Gray (1972) proposed that note-taking facilitates learning in two important ways, providing not just what these authors termed an *external storage benefit*, but providing in addition what they termed an *encoding benefit*. More specifically, they argued that note-taking does not just help by recording lecture information for us to restudy later; importantly, note-taking also helps at the time of the lecture by promoting the encoding of information in ways that facilitate later retrieval (e.g., by encouraging deeper processing of lecture information, as suggested by Kiewra, 1985). DiVesta and Gray's seminal paper stimulated considerable research on note-taking concerned with assessing the independent contributions of encoding and storage to the overall effects of lecture note-taking and with determining which of these processes plays a larger role in driving the benefits of note-taking.

In most of the studies exploring the encoding benefit, students listened to a lecture and were randomly assigned to groups which either took notes during the lecture or just listened without taking notes. In order to isolate the encoding benefit, students in these studies were not allowed to review their notes prior to being tested for their memory of the lecture material. A review by Kiewra (1985) identified 56 such studies, of which 33 found a beneficial effect of note-taking. In short, a significant effect was observed in most cases, but the evidence for an encoding benefit from note-taking was far from unanimous. Moreover, although knowing that an effect is observed 59% of the time speaks directly to its replicability, it provides only indirect evidence of the size of the effect. After all, effects can be inconsistent, perhaps because of unspecified moderating variables, and yet be large when they occur.

To address these issues, Kobayashi (2005) conducted a meta-analysis of studies that compared no note-taking to note-taking without restudy. Overall, Kobayashi found a small positive effect of note-taking (Cohen's $d = .26$), consistent with the results of Kiewra's (1985) review. Importantly, however, the largest effect sizes were observed for free recall tests, whereas the smallest effects (not counting cases where the type of test could not be determined) were for recognition

☆ We thank Sandy Hale, Geoff Maddox, and John Nestojko for helpful comments at various stages of this work.

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http://dx.doi.org/10.1016/j.lindif.2014.05.002
1041-6080/

tests (average Cohen's *ds* for free recall and recognition tests of .55 and .18, respectively).

Examining a number of other potential moderator variables, Kobayashi observed that the encoding benefit was smaller when the presentation mode could be visually distracting, as in the case of an actual or filmed lecturer, compared to an auditory recording. Noting that previous research indicated that presentation mode does not affect learning from lectures when notes are not taken, Kobayashi concluded that in studies of note-taking, presentation mode may moderate the encoding benefit because writing requires visual attention (e.g., to prevent going off of the page), and thus attention to other visual stimuli may limit the ability to take handwritten notes.

Kobayashi's (2005) interpretation is consistent with research showing that note-quantity is a powerful predictor of test performance even when students are not allowed to restudy their notes (e.g., Aiken, Thomas, & Shennum, 1975; Fisher & Harris, 1973). For example, Bui, Myerson, and Hale (2013), following up on prior findings showing that (except in novices) typing is usually faster than handwriting (Brown, 1988), had participants take lecture notes either by typing on a computer keyboard or by writing them. When participants were told to try and transcribe a lecture, typing using a computer not only led to greater note-quantity compared to taking handwritten notes, it also led to better memory for the lecture material. Moreover, similar effects of note quantity are obtained when students are allowed to study their notes (e.g., Crawford, 1925; Kiewra & Benton, 1988; Kiewra, Benton, Kim, Risch, & Christensen, 1995; Nye, Crooks, Powley, & Tripp, 1984). For example, in two experiments in which study time was given, Peverly et al. (2007) found that transcription speed, as measured by both an adapted version of the alphabet task (Berninger, Mizokawa, & Bragg, 1991) and the Woodcock–Johnson Writing Fluency subtest (Woodcock & Johnson, 1989), was a significant predictor of notes, which in turn was predictive of test performance.

Evidence for an external storage benefit is robust (for a recent review, see Kobayashi, 2006), and relative to the encoding benefit, appear to be more reliable. In studies examining the storage benefit, students typically listen to a lecture while taking notes. Afterwards, some students are allowed to review their notes, whereas others are not. However, all students are then tested for their memory of the lecture material. In the same review by Kiewra (1985) that examined the encoding benefit, 17 of the 22 identified studies found that reviewing notes resulted in higher test performance, a finding subsequently replicated by Kiewra et al. (1991).

The higher degree of consensus among relevant studies regarding the external storage benefit (77%) compared to the encoding benefit (59%) in the literature reviewed by Kiewra (1985) raises the question as to which function is more important. Whereas some studies found the encoding function to be more beneficial (e.g., Annis & Davis, 1975; Barnett, DiVesta, & Rogozinski, 1981), others reported the external storage function was more important (e.g., Fisher & Harris, 1973; Howe, 1970; Kiewra et al., 1991; Rickards & Friedman, 1978). However, because utilizing both aspects of note-taking in conjunction appears to be a more potent learning tool than either aspect on its own (e.g., Fisher & Harris, 1973; Kiewra, DuBois, Christensen, Kim, & Lindberg, 1989), Kiewra (1985) pointed out that from the perspective of advancing educational instruction, it may serve little purpose to focus solely on comparing each component's contribution.

3. Cognitive demands in lecture note-taking

Despite its benefits, lecture note-taking can be cognitively demanding, as it typically involves students having to pay attention to a lecture, temporarily holding onto the information provided while simultaneously organizing that information, and then having to write it down before it is forgotten. Perhaps as a result, students may adopt different note-taking strategies whose effectiveness can vary for a number of reasons, among them being individual differences in cognitive ability. That is, the degree of efficiency with which certain cognitive operations can be performed varies from one individual to another, and these individual differences influence how well people are able to perform a complex task such as note-taking.

One cognitive ability that seems like it should be important for lecture note-taking is working memory, which has been defined as the ability to temporarily hold and manipulate limited amounts of information (Baddeley, 1986, 2007). Early conceptualizations of working memory tended to focus on short-term storage and rehearsal (e.g., Atkinson & Shiffrin, 1968). Newer conceptualizations, however, cover much more than this, and accordingly, working memory has been extensively studied under conditions that require not just maintaining items in memory, but also coordinating and switching back and forth between multiple tasks (e.g., Baddeley, Chincotta, & Adlam, 2001; Engle, Tuholski, Laughlin, & Conway, 1999). Such multi-tasking is obviously a fundamental aspect of lecture note-taking, and indeed, holding onto information while multi-tasking is, at least for some researchers, the very essence of working memory (Engle et al., 1999).

It should be noted, however, that the term working memory has been used in quite different ways by different researchers. For example, some cognitive neuroscientists, particularly neurophysiologists, have studied working memory using tasks that require temporary maintenance of only a single item (e.g., a spatial location or to-be-remembered response; for a review, see Goldman-Rakic, 1996). Other cognitive neuroscientists, particularly those using neuroimaging, have used *n*-back tasks that require constant updating of information about the most recent *n* items (for a review, see Owen, McMillan, Laird, & Bullmore, 2005). Experimental psychologists and individual-differences researchers have studied working memory using both traditional memory span tasks and complex span tasks that interleave irrelevant processing tasks with presentation of to-be-remembered items (Conway et al., 2005).

Both the difference, if any, between the abilities tapped by simple and complex span tasks and the role of these abilities in higher-order cognition remain controversial (e.g., Colom, Rebollo, Abad, & Shih, 2006; Engle et al., 1999; Unsworth & Engle, 2007b). In addition, *n*-back tasks and complex span tasks have proved to be only weakly correlated (Redick & Lindsey, 2013). As a result, we have chosen to use a broad definition of working memory here, and to review the literature that examines a variety of functions (e.g., the storage, forgetting, and transformation of temporarily stored information) that are included in current models of working memory, even if the tasks used to assess these functions tap only one aspect of what some researchers would consider working memory.

Perhaps the most well-known model of working memory is that of Baddeley (1986; Baddeley & Hitch, 1974), who proposed that the working memory system includes not only content-specific storage components (the phonological loop and visuo-spatial sketchpad for verbal and visuospatial information, respectively), but also a processing component (the central executive) that performs a wide range of functions, including directing attention to relevant information, inhibiting irrelevant information and/or actions, and coordinating cognitive processes when more than one task must be done at the same time. More recently, Baddeley (2000) added a new component, the episodic buffer, to his model to allow for the interaction between the two storage components, as well as to account for the contributions of long-term memory to performance on working memory tasks.

Baddeley's (1986, 2007) model has been successful in explaining many findings in the short-term and working memory literature, as well as in stimulating further research. More recently, however, other models have emerged that provide alternative accounts of the processes that underlie working memory function. These models differ with regards to issues such as the contribution of long-term memory to working memory function, the nature of working memory's limited capacity, and the role of attention in working memory (for reviews of various models and theories, see Conway, Jarrold, Kane, Miyake, & Towse, 2007; Miyake & Shah, 1999).