Research Article

Anna L. Ostendorf, Helge Schlüter, Ryan P. M. Hackländer*

Sounds in the classroom: Auditory context-dependent memory in school-aged children

<https://doi.org/10.1515/psych-2020-0101>

Received January 18, 2020; accepted April 16, 2020

Abstract: Context-dependent memory (CDM) is the effect whereby information is retrieved more accurately in the presence of the contextual information that was present during encoding than in the absence of that contextual information. Most previous CDM experiments have focused on spatial location, but contexts such as sights, smells, and sounds have also been shown to be effective mnemonic cues, although the research is more limited. In relation to auditory contexts, much of the previous research has focused on music and on adults. We were interested in determining whether auditory CDM effects could be found in a classroom setting in school-aged children using background noises. Across two experiments we found that the reinstatement of the auditory context improved memory performance for 2nd, 3rd, and 5th grade students. Sounds, not just musical pieces, are stored in memory and can be effective contextual mnemonic cues. Further, (auditory) CDM effects can be found in young children. Teachers should be aware of the influence of contextual auditory cues in the classroom setting, and how this information is stored along with the focus of the teaching lesson.

Keywords: context-dependent memory; memory; classroom; education; sounds; context

Introduction

There are many instances in life when one attempts to encode a particular piece of target information, such as when you are having a conversation with another person and they say something interesting that you want to try to remember later. Target information, however, does not appear in a vacuum, but is always experienced in an information rich external environment and in a particular internal state. Research has shown that details of the context (which is comprised of both the external environment and internal factors present during encoding) are also encoded and stored with the target information (Isarida & Isarida, 2014; Ucros, 1989).

One important question revolves around what types of stimuli can function as contextual mnemonic cues. The majority of research on CDM has focused on place or location as a context (see Smith & Vela, 2001 for a review). However, other contexts have been tested as well; including simple visual backgrounds like colors, video backgrounds, mood, odors, and auditory contexts (see Isarida & Isarida, 2014 for a review). The current study focuses on one of the least studied aspects of CDM, namely auditory CDM.

Article note: This article is part of Special Issue Experimental Cognitive Psychology

*Corresponding author: Ryan Hackländer, University of Hildesheim, Department of Psychology, Universitaetsplatz 1, D – 31141 Hildesheim, Germany, E-mail: hacklaen@uni-hildesheim.de

Anna L. Ostendorf, Helge Schlüter, University of Hildesheim, Department of Psychology, Universitaetsplatz 1, D – 31141 Hildesheim, Germany

To this point, only a limited amount of research has investigated auditory CDM. However, this limited amount of research has shown that auditory information can act as retrieval cues to produce robust CDM effects (Smith, 1985). Most of the research in this area has focused on music (e.g., Balch & Lewis, 1996). However, the research with music has led to difficulties in interpretation, as it is unclear whether the CDM effects are due to the reinstatement of specific musical pieces (Isarida, Kubota, Nakajima, & Isarida, 2017), reinstatement of tempo (Balch, Bowman, & Mohler, 1992; Balch & Lewis, 1996), reinstatement of key or tonality (Mead & Ball, 2007), or reinstatement of a general mood (see Isarida et al., 2017 for a discussion). A more limited amount of research has also shown that noises can also produce CDM effects (Grant et al., 1998; Smith, 1985).

In an early study on auditory CDM with noises, Smith (1985, Exp. 2) had subjects learn a list of words in the presence of either jazz music, white noise, or silence. After a 48-hour delay subjects completed a free recall test for the words from the learning phase. One third of subjects from each condition completed the recall test in the presence of music, white noise, or silence (i.e., the study conformed to a 3 x 3 design). Smith found that subjects who learned and were tested in the presence of the same auditory context (jazz or white noise) outperformed (i.e., forgot less than) subjects who either learned and were tested in the presence of silence or who had different auditory contexts between the learning and test phases.

There are two key aspects of these findings that are worth highlighting in more detail, because of their relevance to our arguments, and the discussion of our findings. Firstly, it is worth highlighting that the group that had white noise present in both the learning and testing phases outperformed the group that learned and was tested without the addition of any background noise. This context enhancement effect is important, because it could have been the case that background noise is, in general, detrimental to performance on cognitive tasks (see Bell et al., 1984 for a discussion of this point). Secondly, it is important to note that neither the presence of music or noise in the retrieval phase enhanced memory when it was not the same auditory context as that which was presented in the learning phase.

In a second study which found auditory CDM effects with noises, Grant and colleagues (1998) had subjects read an article on immunology either in a silent room or in the presence of background noises. In this study the background noises were from a recording of ambient sound in a school cafeteria. After a short 2-minute retention interval subjects performed several different tests, including a free recall test (short answer) and a recognition test (multiple choice) about the article. The authors found that subjects who were tested under the same conditions as those in which they read the article performed better than subjects who switched conditions (for both the recall and recognition tests). The major difference between this study and that from Smith is that Grant and colleagues did not find context enhancement effects (i.e., the noise-noise condition did not outperform the silence-silence condition).

One other study investigated the effects of reinstating contextual noises as memory cues (Bell et al., 1984). In this study, subjects learned four word lists, each containing 28 words. Each list was immediately followed by a free recall test. During the learning of two of the word lists subjects were exposed to 55db background noise. During the free recall phases for these lists, subjects were one time exposed to 55db background noise and one time exposed to 95db background noise. The other two word lists were learned in the presence of 95db background noise, and again one recall phase was completed in 55db and one in 95db background noise. The authors found no context reinstatement or enhancement effects. Rather, they found that the presence of 95db noise during learning was detrimental to later memory performance.

While these results could be interpreted as counter-evidence to the finding of auditory CDM with noises, there are several reasons we think the results should not be interpreted as such. For one, it is not entirely clear from the method section of the paper that the noises present in the same and different background conditions were actually different, or whether they were the same sound played at different volumes. If only the volume was changed, then it could be that the auditory context was always reinstated, if the key feature is the identity of the noise, rather than the volume, which acts as a mnemonic cue. Furthermore, the recall phase was performed immediately after the learning of each list. This means that in the “reinstatement” conditions, the context was never actually reinstated, because it remained the same throughout the entire trial. Contextual cues are most useful as mnemonic aids when there has been a shift and then a reinstatement of the context. This is especially shown in that longer retention intervals generally lead to

larger CDM effects (Smith & Vela, 2001).

The CDM studies with noises provide important information about the ability for noises to act as mnemonic cues. However, any conclusions are based on a limited sample of studies and any further research into this area would necessarily bring more clarity. One open question is whether the findings apply to children. All three of the studies with noises, and nearly all CDM studies in general, used adults (mostly university students) as subjects (though there are several mood-state dependent memory studies which have found effects in children; Bartlett & Santrock, 1979; Bartlett, Burleson, & Santrock, 1982; but see Duncan, Todd, Perlmutter, & Masters, 1985). Given that the effectiveness of mnemonic cues increases with age (Kobasigawa, 1974), it is plausible to think that auditory CDM effects are different in adults and children, and perhaps only present in adults.

One of the only CDM studies that used children as subjects (Cassaday, Bloomfield, & Hayward, 2002, Exp. 2) found CDM effects on a recall test. In this study, the authors induced a “relaxing” context with the aid of a calming odor, classical music, dimmed lighting, and the behavior of the experimenter. They found that children who learned the test material and performed a recall test in the presence of the calming condition outperformed children who switched contexts between phases or learned and were tested in a neutral context (no “added” relaxing stimuli).

While Cassaday and colleagues clearly found CDM effects in their study with children, it is important to note that it is not clear what part of the “calming” background was associated with the target material, whether all of the various background features were individually associated with the target and their reinstatement led to additive CDM effects, or whether they were all associated with the target as an ensemble context. Given that not only music, but also odors (e.g., Hackländer & Bermeitinger, 2017) and visual stimuli (e.g., Isarida & Isarida, 2007) have been shown to be effective mnemonic cues, it is possible that either of those cues were driving the effects, and not the auditory cues. Therefore, it is theoretically important to look at auditory cues independently to know whether they can act as effective contextual mnemonic cues in children.

More generally, it is important to gather more evidence about whether and when CDM effects will occur in children. This is particularly important, because one of the main areas in which CDM research can be of practical relevance is in educational settings. Indeed, knowing how to use the environmental context to benefit learning could potentially be a great way to improve performance in schools and lead to more, long-term retention of learned material.

As one example of the potential benefits of CDM research for an educational setting, we would like to highlight findings by Isarida and colleagues showing that the effects of study time are dependent on whether the context was reinstated or not (e.g., Isarida, 2005; see also Isarida & Isarida, 2014 for a reanalysis of data from multiple experiments). A classic finding in memory research is that increased study time leads to increased memory performance later. Isarida and colleagues have found, however, that the increase in study time is particularly beneficial when testing takes place in the same context as learning. One explanation for this finding is that the increased study time not only allows one to increase the strength of the memory trace for the target, but also allows for increased strength of association between the target and the context.

There is clear practical relevance in knowing that increasing study time is particularly useful when the testing context is the same as the learning context. For educators, this knowledge can be used to encourage longer learning/studying when it is known that later testing will occur in the same context. For the learner, it is also useful to know that longer studying in a different context from that in which the testing will occur (e.g., studying at home) has limits, and the time may be best invested in other ways than simply attempting longer studying of particular target material.

The relevance of CDM research to education has been acknowledged for some time. Indeed, one early study found CDM effects in an educational setting (Abernathy, 1940; but see, Metzger, Boschee, Haugen, & Schnobrich, 1979; Farnsworth, 1934; Saufley Jr., Otaka, & Bavaresco, 1985; see Smith, 1988 for a discussion). In Abernathy’s study, which was performed over a five year period, university students from various classes had their memory assessed for a variety of different topics (e.g., The Nervous System). Essentially, the conditions important for the study were whether students were tested a) in the original classroom, with the

original instructor, b) in a different classroom, with the original instructor, c) in the original classroom, with a different instructor, or d) in a different classroom, with a different instructor. The researchers found that performance was best when the test was taken in the presence of the original instructor in the same classroom (a). Furthermore, it was reported that having one of the key variables (instructor (b) or room (c) or) reinstated at test also improved memory performance above the group in which neither was reinstated (d).

The presence of context-dependent memory effects makes it clear that the context in which information is learned and retrieved is not trivial and should receive more attention from researchers interested in education improvement. One of the key environmental factors present in the classroom is the background or ambient sound. This is a key feature of the context in a classroom for several reasons.

Firstly, it is unlikely that this feature is frequently attended to, unless there is a distracting noise that is present. Secondly, there is a good chance that the background noise present in a classroom is relatively stable over time. Finally, the background noise that is present in the classroom is a feature that can easily be manipulated by the individual teacher (e.g., by playing recorded noises, ensuring that students are quiet, etc.). If it can be shown that auditory CDM effects can be found in children, in educational settings, then teachers could use this knowledge to their advantage to manipulate the ambient auditory environment to best suit learning and testing performance in their students.

Driven by the potential practical importance of auditory CDM research for education, the current experiments aimed to determine whether auditory CDM effects could be found with children. In particular, we aimed to test whether CDM in children could be found using sounds (as opposed to music), whether auditory CDM could be found with both recall and recognition tests, and whether the auditory CDM effects in children were independent of age.

In addition to the theoretical interest in auditory CDM effects we were interested in the potential practical relevance of such findings in an educational setting. This was of particular relevance in the current case, because some of the data were collected within the framework of a university class (Projektband at the University of Hildesheim) in which future teachers learn how to perform experimental studies. This both influenced our motivation to perform the research in a way that could have potential practical implications for educators, as well as constrained the samples we could recruit and the experimental controls we could employ. Indeed, due to our interest in the practical relevance of the findings, we decided to break the mold of most other CDM research and test our hypotheses outside the laboratory. Instead, we performed our CDM experiments in the field, specifically with children who participated in their own classrooms.

Experiment 1

In Experiment 1, we aimed to determine whether CDM effects could be found in school-aged children. Specifically, we were interested in determining whether the reinstatement of an auditory context, which was composed of sounds of the North Sea, improved recall if the sounds were present during the learning of a list of words. It is important to note that these data were collected within the framework of a university class, as described above. In this class students are assigned to a classroom in a school to gain practical teaching experience. During their time there, they are required to perform an independent investigation. A group of university students, including the first author, performed the current study in tandem. Importantly, each university student was only able to collect data from one classroom, which limited the sample we collect. Furthermore, this also meant that the conditions were not randomly assigned, but rather that each classroom could only participate in a single condition together (this is detailed below). Additionally, two of the groups were collected as part of the first author's Master thesis.

Design

The current study conformed to a 2 (Reinstatement type: Reinstatement vs No reinstatement) x 2 (Grade: 2nd vs 5th) design. Both variables were manipulated between-subjects. The dependent variable of interest was the proportion of words recalled.

Method

Participants

Subjects were all either second (generally 7 and 8 year olds) or fifth graders (generally 10 and 11 year olds) from classrooms in Hildesheim, Germany. One second grade ($n = 25$) and one fifth grade ($n = 16$) classroom were assigned to the No-reinstatement groups and the other second ($n = 18$) and fifth grade ($n = 27$) classrooms were assigned to the Reinstatement groups. A sensitivity analysis, with the aid of G*Power, shows that with the current sample, an alpha level of .05, and a power of .8, we would be able to find an effect of $d = .54$ for the main effect of reinstatement with a one-sided t test. Note that this leaves out the consideration of any interaction effects, as our main concern was the main effect of reinstatement.

Due to the nature of the project, sex and age of the subjects were not collected. This was done to ensure anonymity of the data, as such information, in combination with the knowledge of which classrooms were used, could be used to identify the individual subjects. In general, the classrooms were comparable. The second grade groups were collected at primary schools (Grundschulen) near Hildesheim, Germany, while the fifth grade groups were collected at secondary schools (Gesamtschulen) near Hildesheim, Germany.

Procedure

Subjects were first seated in a circular formation around a speaker, which was connected to a smartphone. Although exact measurements were not made, the experimenter attempted to arrange the seating so that all subjects were equidistant from the speaker within each classroom. Given that distance was not measured, it is likely that the distance to the speaker differed between the groups. The same speaker was used in each group and the volume was always set to the maximum level. All subjects in all groups always received the exact same instructions.

During the learning phase all subjects were informed that they would be given sheets of paper, handed out upside-down, and should wait to flip them over until the experimenter said so. The experimenter informed the subjects that they would have two minutes to read and memorize the words on the paper (intentional learning procedure). Each paper contained 20 words from a German database (Grundwortschatz 500) which contains the most common words used in the German language (see Appendix A for a list of words used). The words were written in Calibri, 14-point font and were presented in two columns on the paper. These words were chosen to ensure that all students were familiar with the to-be-learned material.

After all papers had been distributed the experimenter told the students to flip over the paper. Simultaneously, the speaker was turned on and the children studied the list of words in the presence of the auditory context for two minutes. The auditory context was a recording of the sounds of waves from the North Sea (use this OSF link for access to the recording: <https://osf.io/92dps/>). At the end of two minutes the speaker was turned off and subjects were required to flip over their paper. There was a one minute retention interval in which students were required to remain silent while their papers were collected and new, blank sheets of paper were distributed.

At the end of the retention interval, subjects were told to pick up the blank sheet of paper and write down as many words as they could remember from the learning phase. In the Reinstatement groups the speaker was again turned on and subjects completed the recall test in the presence of the sounds of waves. Subjects in the No-reinstatement groups completed the recall test in silence. Subjects were given three minutes to complete the recall task, after which time all papers were collected and subjects were thanked for their participation.

Results

The proportion correct on the recall test were submitted to a 2 (Reinstatement group: reinstatement vs no-reinstatement) $\times$ 2 (Grade: second vs fifth) between-subjects ANOVA. The ANOVA revealed main effects

of both Reinstatement group, $F(1, 82) = 13.18, p < .001, \eta_p^2 = .14$, and Grade, $F(1, 82) = 13.65, p < .001, \eta_p^2 = .14$. There was no interaction between the two variables, $F(1, 82) = 0.05, p = .831, \eta_p^2 < .01$ (see Table 1).

Independent sample t -tests (with Bonferroni corrections, critical $\alpha = .025$) were performed to determine whether the CDM effect was significant in both the second grade and fifth grade samples (see Table 1 for means and standard deviations). For the second grade sample the t test revealed a significant main effect whereby reinstatement of the context led to a higher proportion correct than no reinstatement, $t(41) = 2.75, p = .009$, Cohen's $d = .84$. A power analysis with the aid of G*Power showed that the achieved power was .85. For the fifth grade sample the t test also revealed a significant main effect whereby reinstatement of the context led to a higher proportion correct than no reinstatement, $t(41) = 2.39, p = .022$, Cohen's $d = .72$. A power analysis with the aid of G*Power showed that the achieved power was .73. These analyses make it clear that reinstatement of an auditory context improved recall, regardless of the age of the students.

Table 1. Proportion correct on an immediate recall test as a function of auditory context reinstatement and school grade

	Second grade	Fifth grade	Across Grade
Reinstatement	.47 (.15)	.58 (.12)	.53 (.15)
No Reinstatement	.34 (.14)	.47 (.18)	.39 (.16)
Across Reinstatement Group	.40 (.16)	.54 (.15)	.47 (.17)

Note. Mean proportion correct. Values in parentheses represent the standard deviations.

Discussion

Auditory CDM effects were found with school-aged children in a classroom setting in which sounds of the North Sea were used as the background context. The results were found to be independent of age, as CDM effects were found in both the second and fifth graders. The results of this study are theoretically interesting for several reasons. For one, to the best of our knowledge, this is the first evidence of auditory CDM effects being found in school-aged children, and one of the first studies to find any evidence of CDM in children (Cassaday et al., 2002), at least when context is considered to be external to the subject (see Bartlett & Santrock, 1979 for a state-dependent memory study in children). While previous CDM effects have been found in babies (Rubin, Fagen, & Carroll, 1998; Schroers, Prigot, & Fagen, 2007), including auditory CDM effects (Fagen et al., 1997), the methods used for studying such populations are necessarily quite different than those used to study CDM effects in adults. Here we show CDM effects with a standard recall test, which is comparable to most previous CDM research. One important implication is that findings related to CDM effects found in adults may be applicable to younger individuals, and that there may be no differences in what information in a situation is encoded, depending on the stage of development.

Another reason these findings are interesting is that these are among the first results to show auditory CDM effects (see Isarida & Isarida, 2014), especially with auditory stimuli other than pieces of music (Bell et al., 1984; Grant et al., 1998; Smith, 1985, Exp. 2). There are several important open questions concerning auditory CDM, including whether the effects are due to mood, timbre, tonality, or the specific auditory information transmitted. Given that the sounds of waves do not have timbre or tonality (at least not in the way these attributes are relevant for an analysis of a piece of music), it is clear that auditory CDM cannot be (exclusively) due to these aspects of music. Given the repetitive nature of the sounds of waves (which is not necessarily true of musical pieces) it could be that the auditory information is stored as a single unit. Furthermore, it is likely that all subjects have visual and emotional associations with the sounds of waves, which is not likely to be the case with the musical pieces chosen for previous research (i.e., generally pieces chosen to be unknown to most subjects). The influence of these differences will need to be investigated with future research.

In addition to the theoretical implications of the current findings, there are also important practical implications. Given that the results were found with school-aged children in classroom settings, a clear

implication is that the target, or to-be-learned, information is not the only information encoded when children are learning in a classroom setting. Teachers should be aware of this fact, as children are likely to associate aspects of their environment with the information they are learning. A further implication of this fact is that children are likely to perform better on tests if those tests are held in the same context as where the children learned the information originally. This may be most relevant when test performances are compared between different classes or individuals. If certain classes undertake the test in the same context as that in which they learned the material, but other classes have a change of context (e.g., switched rooms, different auditory settings, redecoration of classroom, etc.) it leads to an unfair comparison between the two classes.

Although the implications are potentially large, we urge caution in over interpreting the current results as many factors were not controlled for. For example, in the current experiment we only used a single type of test, free recall. Given previous findings showing CDM effects to be less likely with recognition tests (e.g., Smith, Glenberg, & Bjork, 1978; but see Smith & Vela, 2001), it was unclear whether we should expect CDM effects for both test types. The variable of test type (recall or recognition) is, then, of both theoretical and practical interest.

The theoretical interest of the variable of test type is clear. If auditory CDM effects (with noises) can be found for both recall and recognition tests, then it shows that reinstatement of the auditory context does not only help in memory search, but also in discrimination of whether a stimulus was previously seen or not. On a more practical note, it is important to know when CDM effects should be expected. Both recall and recognition tests are used frequently in schools, and knowing whether reinstatement of the auditory context will help on only certain types of tests is crucial to effectiveness of CDM techniques being used by educators to improve learning.

Experiment 2

In Experiment 1, we found clear CDM effects in school-aged children when using an immediate recall test. Previous research has, however, shown that the type of test may influence whether CDM effects can be found, specifically with CDM effects being less likely to have been found with recognition than recall tests (e.g., Godden & Baddeley, 1980, but see Smith & Vela, 2001 for a review showing equal effect sizes between test types). Given that many of the tests used in educational settings are actually recognition tests (e.g., multiple choice tests), we wished to determine whether CDM effects in school-aged children could also be found with a recognition test.

It is important to note here, that the data for this experiment were also collected within the framework of the university class described above (Projektband). This led to the same limitations of sample collection and random assignment as those expounded upon in Experiment 1.

Design

The current study conformed to a simple between-subjects comparison with two levels of the independent variable 2 (Reinstatement type: Reinstatement vs No reinstatement). Three dependent variables were of interest, the proportion of hits, the proportion of false alarms, and a standardized measure of accuracy, d' .

Method

Participants

Subjects were all third graders (generally 8 and 9 year olds) from classrooms in Hildesheim, Germany. One classroom was assigned to the No-reinstatement group ($n = 17$) and the other classroom was assigned to the Reinstatement group ($n = 21$). A sensitivity analysis, with the aid of G*Power, shows that with the current sample, an alpha level of .05, and a power of .8, we would be able to find an effect of $d = .83$ with a one-sided

t test. Again, due to the nature of the project, sex and age of the subjects were not collected. In general, the classrooms were comparable, although they were collected from different primary schools (Grundschulen) in Hildesheim.

Procedure

The procedure was the same as in Exp. 1, with the following exception. Instead of receiving a blank sheet during the test period, subjects were handed, upside-down, a sheet with 40 words on it (all taken from the Grundwortschatz 500; see Appendix A for a list of words). Half of the words were learned in the encoding phase and half of the words were new. Subjects were instructed to circle all the words which had been learned in the encoding phase. To ensure that all subjects began the test at the same time, the experimenter gave a signal when all the subjects should flip over the paper and begin with the test. At this time, the sound of the waves was also reinstated, in the Reinstatement group. The subjects had 3 minutes to complete the test. After the time limit, the experimenter stopped the North Sea sounds (in the Reinstatement group) and collected all the papers.

Results

Proportion of hits

The independent samples *t* test revealed a significant effect of Reinstatement type, as the Reinstatement group had a higher proportion of hits ($M = .83$, $SD = .13$), than the No-reinstatement group ($M = .74$, $SD = .15$), $t(36) = 2.06$, $p = .046$, Cohen's $d = .67$. A power analysis with the aid of G*Power showed that the achieved power was .64.

Proportion of false alarms

There was no effect of Reinstatement type, as the Reinstatement group ($M = .07$, $SD = .06$) and the No reinstatement group ($M = .06$, $SD = .07$) committed a statistically equivalent number of false alarms, $t(36) = 0.49$, $p = .626$, Cohen's $d = .16$.

d' . The *t* test revealed a significant effect of Reinstatement type, as the Reinstatement group was more accurate ($M = 2.94$, $SD = .80$), than the No reinstatement group ($M = 2.41$, $SD = .67$), $t(36) = 2.17$, $p = .037$, Cohen's $d = .71$. A power analysis with the aid of G*Power showed that the achieved power was .69.

Discussion

The findings clearly show that, even with recognition tests, auditory CDM effects can be found in school-aged children in a classroom setting. This is also among the first evidence of auditory context-dependent memory effects with recognition tests, in either adults or children (Grant et al., 1998). This is particularly important for educational settings, as teachers frequently use recognition tests to assess memory and academic performance in the classroom.

General discussion

In traditional teaching settings, the teacher has a focal piece of information that they aim to teach the student(s). However, research in cognitive psychology has long shown that information is not learned in a vacuum, and contextual information is frequently stored in association with target information (e.g., Dulsky, 1935; Skinner, 1948). This is most clearly displayed with context-dependent memory (CDM) effects,

whereby information is better retrieved in the context in which it was learned than in another context (Godden & Baddeley, 1975).

Although teachers do pay a great deal of attention to the environment in which they teach, there is rarely a consideration of how the context is bound in memory to the focal information being taught. While this makes sense from a practical viewpoint, research on CDM has shown that target information is generally stored in memory in association with contextual information (Isarida & Isarida, 2014). Therefore, research on CDM in the classroom is of importance for learning what contexts are stored with target information, in which situations, and how contexts can be used to enhance learning.

To this point, CDM research in classrooms has generally focused on the place/location aspect of the classroom (Abernathy, 1940). The most relevant finding here is that being tested in a location other than where the information was learned is detrimental to memory performance (see Smith & Vela, 2001 for a review). However, the classroom environment is composed of a number of contextual elements, including temperature, lighting, auditory context, etc.

In the current studies we focused on the auditory context in the classroom. In particular, we were interested in whether auditory CDM could be found with sounds (as opposed to music) in school-aged children. In Experiment 1, we indeed found evidence of auditory CDM using a recall test (Cohen's $d = .91$). Of note, we found that the effect was independent of age, as it was present in both second and fifth grade classes. In Experiment 2, we conceptually replicated the finding of auditory CDM in young children, but extended the finding by using a recognition test (Cohen's $d_{\text{hits}} = .67$, $d_{\text{d'}} = .71$). This is theoretically important because recognition tests have been theorized (see Smith & Vela, 2001) and found (Godden & Baddeley, 1980) to reduce CDM in the past. The finding of auditory CDM with recognition tests is also practically important, as many tests in the school setting are actually tests of recognition (e.g., multiple choice questions).

Our findings are, to the best of our knowledge, the first to show auditory CDM effects in children. This is important, because past research has indicated that contextual information may be used differently at different stages of development, namely becoming more important with age (Kobasigawa, 1974). Our findings seem to indicate, not only that auditory context is stored in children's memory, but also that this does not develop with age, as similar findings were found in the recall test for second (Cohen's $d = .84$) and fifth graders (Cohen's $d = .72$).

Another point of theoretical interest is that we found auditory CDM effects with sounds, instead of music. This constrains, somewhat, theorizing about what is responsible for auditory CDM effects, as we discuss further under the Mood limitation section below. Indeed, although we feel that our study contributes both theoretically to the CDM literature and practically to educators interested in factors that influence learning in the classroom, there are several important limitations of the study that need to be discussed.

Limitations

There are several limitations in the current experiments that lead us to advise caution in over interpretation of the results. In this section, we highlight some of our main concerns and deal with them on a point by point basis. We then suggest how future research can best address outstanding issues and tackle pressing questions of both theoretical and practical relevance.

Random assignment

The studies reported here were first conducted in the context of a university class in which future teachers are trained in the scientific method. The data collection was performed by the university students in the 2nd, 3rd, or 5th grade classes where they were placed. Therefore, during data collection there was in fact no random assignment of the subjects to the experimental groups. Rather, each group represented a single class and the class performed the experiment together (as explained in the Procedure section of Exp. 1). The lack of random assignment is a limitation of the current study that requires caution in over-interpretation. Future auditory CDM studies with children should have proper random assignment to ensure that effects of

school, class, teacher, etc. can be ruled out.

That being said, the benefit to our method was external, or real-world validity. We performed the experiment in an actual classroom and were able to find auditory CDM effects. Generally, we would expect CDM effects to become weaker, the less controlled the environment (see Smith & Vela, 2001 for a discussion of overshadowing and outshining). This, along with the fact that we replicated the findings from Experiment 1 in Experiment 2, with a different type of test, should lend support to our findings. Furthermore, the real-world validity of our study should make the results all the more relevant to educators.

Extraneous variables

Similar to the issue of random assignment, the fact of how our data were collected means there is potential for extraneous variables to have influenced the results. For example, and as mentioned above, there was no standardization in the distance that subjects sat from the speaker. Also, the researcher and teacher in the classroom was different between the different groups. Furthermore, given that the experiment took place in the field, there was no way to ensure that other background noises were constant across the different groups, although the researchers of course tried to make the rest of the background environment as quiet as possible. While future studies should certainly test our results in a controlled laboratory environment, we believe the real world validity of our studies, the fact that we replicated the results in Experiment 2, and the novelty of our methods, ensure that our results add both theoretical and practical value to the larger research on CDM.

Mood

As we discussed above, there are several potential factors that influence auditory CDM effects. This is most relevant when using music as the background information, in which the musical pieces can vary in tempo, tonality, type, and piece (see Isarida et al., 2017 for a discussion). While the use of sounds in our experiment rules out tempo and tonality as factors necessarily responsible for auditory CDM, the use of the sounds of waves does not rule out mood as a causal factor (indeed, tempo and tonality have generally been used as proxies for studying mood, e.g., Balch et al., 1992).

The sounds of waves are sure to induce emotional reactions, which likely depend on idiosyncratic associations to ocean/sea/beach related stimuli. Therefore, it is likely that listening to these sounds induced an emotional reaction in the children. It could be that the reinstatement of the sounds also reinstated the emotional reaction. This confound makes it impossible for us to determine whether the auditory CDM effects reported here are due to emotion/mood or the memory for a piece of auditory information. Future studies will be needed to disentangle this issue. However, regardless of whether the effects are due to emotion/mood or memory for background auditory information, the implications we discussed above, for both theory in CDM research and for practice in the classroom, stand.

There is a further confound, in that the design was not fully crossed. Therefore, we cannot completely rule out the possibility of the CDM effects reported here being due, not to reinstatement, but rather to the presence of noise in the testing condition alone. For example, it could be that being tested with the presence of calming sounds improves memory performance above being tested in silence. While this is certainly a possibility, there is reason to be suspect of this based on previous CDM research.

For one, Grant and colleagues (1998) had a fully crossed design in their auditory CDM study using noise. They found that the mere presence of background noise did not improve memory performance above the group that performed the test in silence. Furthermore, Balch and Lewis (1996) found that groups that changed music contexts from learning to testing, did not outperform groups that completed both learning and testing in silence (i.e., the mere presence of music during testing did not improve memory performance). Therefore, we urge researchers, if possible, to use a fully crossed design in future CDM studies in educational settings, but we believe the lack of this design does not render moot the theoretical and practical implications of our current findings.

Conclusions

Here we provide the first direct evidence that auditory CDM effects can be found in children tested in their own classrooms. Our results contribute to the growing literature on auditory CDM and CDM in children. One of the main points of theoretical interest is that CDM effects seem to be found independent of age, potentially indicating that how the background is stored in memory does not change throughout the lifespan (Kobasigawa, 1974). Furthermore, we found evidence that auditory CDM can be found with sounds, instead of music, and that the effects are test (recall vs recognition) independent. In addition to theoretical relevance, our results have practical relevance for the educational setting as well. In particular, the results show, at a minimum, that what students are learning in the classroom is much more encompassing than just that which the teachers aim to communicate. Given this knowledge, we suggest that the learning context be given adequate attention in educational settings, especially when it comes to standardized tests with relevance for an individual's future status.

Ethical declaration: All data collection was performed in accordance with the ethical guidelines of the American Psychological Association as well as the World Medical Association's Declaration of Helsinki (revised version from the 64th General Assembly Meeting in Fortaleza Brazil, World Medical Association, 2013) and the experiment was approved by the local IRB (Ethik-Kommission). Informed consent was obtained from parents and teachers and subjects provided verbal assent after being made aware that their participation was voluntary and could be terminated at any time without the risk of penalty.

Conflicts of Interest: The authors have no conflicts of interest to declare.

Financial statement: This research received no specific grant from any funding agency, commercial, or non-profit sectors.

Acknowledgments: This project was a combination of a class project, which the first author was a part of and the last author led, and the first author's Master's thesis.

We thank Fabian Fricke and Theresa Habermann for their assistance in data collection and planning of the original data collection.

References

- Abernethy, E. M. (1940). The effect of changed environmental conditions upon the results of college examinations. *The Journal of Psychology*, 10, 293-301.
- Balch, W. R., Bowman, K., & Mohler, L. A. (1992). Music-dependent memory in immediate and delayed word recall. *Memory & Cognition*, 20, 21-28.
- Balch, W. R., & Lewis, B. S. (1996). Music-dependent memory: The roles of tempo-change and mood mediation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 22, 1354-1363.
- Bartlett, J., C., & Santrock, J. W. (1979). Affect-dependent episodic memory in young children. *Child Development*, 50, 513-518.
- Bartlett, J. C., Burleson, G., & Santrock, J. W. (1982). Emotional mood and memory in young children. *Journal of Experimental Child Psychology*, 34, 59-76.
- Bell, P. A., Hess, S., Hill, E., Kukas, S. L., Richards, R. W., & Sargent, D. (1984). Noise and context-dependent memory. *Bulletin of the Psychonomic Society*, 22, 99-100.
- Cassaday, H. J., Bloomfield, R. E., & Hayward, N. (2002). Relaxed conditions can provide memory cues in both undergraduates and primary school children. *British Journal of Educational Psychology*, 72, 531-547.
- Dulsky, S. (1935). The effect of a change of background on recall and relearning. *Journal of Experimental Psychology*, 18, 725-740.
- Duncan, S. W., Todd, C. M., Perlmutter, M., & Masters, J. C. (1985). Affect and memory in young children. *Motivation and emotion*, 9, 391-405.
- Fagen, J., Prigot, J., Carroll, M., Pioli, L., Stein, A., & Franco, A. (1997). Auditory context and memory retrieval in young infants. *Child Development*, 68, 1057-1066.
- Farnsworth, P. R. (1934). Examinations in familiar and unfamiliar surroundings. *Journal of Social Psychology*, 5, 128-129.

- Godden, D. R., & Baddeley, A. D. (1975). Context-dependency memory in two natural environments: Land and underwater. *British Journal of Psychology*, 66, 325-331.
- Godden, D. R., & Baddeley, A. D. (1980). When does context influence recognition memory? *British Journal of Psychology*, 71, 99-104.
- Grant, H. M., Bredahl, L. C., Clay, J., Ferrie, J., Groves, J. E., McDorman, T. A., & Dark, V. J. (1998). Context-dependent memory for meaningful material: Information for students. *Applied Cognitive Psychology*, 12, 617-623.
- Isarida, T. (2005). Study-time effect on free recall within and out of context. *Memory*, 13, 785-795.
- Isarida, T., & Isarida, T. K. (2014). Environmental context-dependent memory. In A. J. Thirnton (Ed.), *Advances in experimental psychology research* (pp. 115-151). New York: NOVA Science Publishers.
- Isarida, T. K., Kubota, T., Nakajima, S., & Isarida, T. (2017). Reexamination of mood-mediation hypothesis of background-music-dependent effects in free recall. *The Quarterly Journal of Experimental Psychology*, 70, 533-543. Doi: 10.1080/17470218.2016.1138975
- Kobasigawa, A. (1974). Utilization of retrieval cues by children in recall. *Child Development*, 45, 127-134.
- Mead, K. L. M., & Ball, L. J. (2007). Music tonality and context-dependent recall: The influence of key change and mood mediation. *European Journal of Cognitive Psychology*, 19, 59-79.
- Metzger, R. L., Boschee, P. F., Haugen, T., & Schnobrich, B. L. (1979). The classroom as learning context: Changing rooms affects performance. *Journal of Educational Psychology*, 71(4), 440-442.
- Rubin, G. B., Fagen, J. W., & Carroll, M. H. (1998). Olfactory context and memory retrieval in 3-month-old infants. *Infant Behavior and Development*, 21, 641-658.
- Saufley, W. H., Jr., Otaka, S. R., & Bavaresco, J. L. (1985). Context effects: Classroom tests and contextual independence. *Memory & Cognition*, 13, 522-528.
- Schroers, M., Prigot, J., & Fagen, J. (2007). The effect of a salient odor context on memory retrieval in young infants. *Infant Behavior and Development*, 30, 685-689.
- Skinner, B. F. (1948). Superstition in the pigeon. *Journal of Experimental Psychology*, 38, 168-172.
- Smith, S. M. (1985). Background music and context-dependent memory. *American Journal of Psychology*, 98, 591-603.
- Smith, S. M. (1988). Environmental context-dependent memory. In G. M. Davies and D. M. Thomson (Eds), *Memory in context: Context in memory* (pp. 13-34). New York: Wiley.
- Smith, S. M., Glenberg, A., & Bjork, R. A. (1978). Environmental context and human memory. *Memory & Cognition*, 6, 342-353.
- Smith, S. M., & Rothkopf, E. Z. (1984). Contextual enrichment and distribution of practice in the classroom. *Cognition and Instruction*, 1, 341-358.
- Smith, S. M., & Vela, E. (2001). Environmental context-dependent memory: A review and meta-analysis. *Psychonomic Bulletin & Review*, 8, 203-220.
- Ucros, C. G. (1989). Mood state-dependent memory: A meta-analysis. *Cognition and Emotion*, 3, 139-169.
- World Medical Association (2013). Declaration of Helsinki: Ethical principles for medical research involving human subjects. *Journal of American Medical Association*, 310, 2191-2194. Doi: 10.1001/jama.2013.281053

Appendix A: Words used in each experiment

Experiment 1

<i>Original German word</i>	<i>English translation</i>
Holz	Wood
Alt	Old
Platz	Place/space
Sonntag	Sunday
Wünschen	To wish
Einfach	Easy
Helfen	To help
Zahl	Number
Frau	Woman
Leise	Quiet
Geschenk	Gift/present
Finger	Finger
Kalt	Cold
Pferd	Horse
Weiß	White
Minute	Minute
Fisch	Fish
Sommer	Summer
stehen	To stand
kommen	To come

Experiment 2

<i>Original German word</i>	<i>English translation</i>
Holz	Wood
Alt	Old
Platz	Place/space
Sonntag	Sunday
Wünschen	To wish
Einfach	Easy
Helfen	To help
Zahl	Number
Frau	Woman
Leise	Quiet
Geschenk	Gift/present
Finger	Finger
Kalt	Cold
Pferd	Horse
Weiß	White
Minute	Minute
Fisch	Fish
Sommer	Summer
Stehen	To stand
Kommen	To come
Nehmen	To take
Musik	Music
Haben	To have
Ding	Thing
Rufen	To call
Opa	Grandfather
Fehler	Mistake
Ferine	Vacation/holiday
Trinken	To drink
Schicken	To send
Apfel	Apple
Stunde	Hour
Wetter	Weather
Monat	Month
Gott	God
Nase	Nose
Steigen	To climb
Ziehen	To pull
Wahr	True/real
Verstehen	To understand

Highlights

- > Context-dependent memory effects found with children
- > CDM effects found with basic sounds
- > CDM effects found in a classroom setting
- > Evidence that non-target information is encoded in addition to target information in a classroom setting
- > Auditory CDM found with both recall and recognition tests