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Influencing Learning Outcomes and Cognitive Load by Adapting the Instructional Design with Respect to the Learner´s Working Memory Capacity and Extraversion

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Abstract

This dissertation aims at further investigating how to match the instructional design of a learning environment to specific learner´s characteristics. More explicitly, the question is raised of who profits from the presence of desirable difficulties (particularly disfluent fonts) or seductive details (particularly background music) with regard to the learner´s working memory capacity and the learner´s extraversion level. Three different empirical studies aim at providing answers: The first study analysed the effect of disfluent fonts on learning outcomes and cognitive load in interaction with the learner´s working memory capacity. The second study investigates how listening to background music while studying a visual text influences learning in interaction with the learners working memory capacity. The third study also investigates the influence of background music on learning outcomes, but in interaction with the learner´s extraversion level and additionally assesses cognitive load. Results of all three studies underline the importance of the aptitude-treatment-interaction approach for the design of a learning environment. Finally, all three studies are discussed and theoretical, methodological, and practical implementations are considered.

Zusammenfassung

Diese Dissertation beschäftigt sich mit der Fragestellung, inwiefern das instruktionale Design einer Lernumgebung an die Lernereigenschaften der Lernenden angepasst werden sollte. Explizit geht es um die Fragestellung, ob Lerner abhängig von ihrer Arbeitsgedächtniskapazität und ihrer Extraversionsausprägung von sogenannten Desirable Difficulties (insbesondere schwer leserliche Schriftarten), beziehungsweise sogenannten Seductive Details (insbesondere Hintergrundmusik) profitieren. Zur Überprüfung der Fragestellung wurden drei empirische Studien durchgeführt: Die erste Studie beschäftigte sich mit den Interaktionseffekten zwischen einer schwer leserlichen Schriftart und der Arbeitsgedächtniskapazität der Lernenden auf den Lernerfolg und die kognitive Belastung. Die zweite Studie analysierte inwiefern das Hören von Hintergrundmusik beim Lernen eines visuellen Texts den Lernerfolg beeinflusst und ob dieser Effekt von der Arbeitsgedächtniskapazität der Lernenden abhängt. Die dritte Studie beschäftige sich ebenfalls mit dem Einfluss von Hintergrundmusik auf das Lernen visueller Texte und den Lernerfolg und berücksichtigt zusätzlich die kognitive Belastung beim Lernen. Als Lernereigenschaft wurde dabei die Extraversionsausprägung der Lernenden miteinbezogen. Die Ergebnisse aller drei Studien unterstreichen die Relevanz Aptitude-Treatment-Interaktionen bei der Gestaltung von Lernumgebungen zu berücksichtigen. Abschließend werden die drei Studien diskutiert sowie theoretische, methodische und praktische Implikationen gezogen.

1 Introduction

"*Learning is not attained by chance, it must be sought for with ardor and attended to with diligence*" (Abigail Adams, 1764).

During the last years, an increasing number of studies were conducted which investigate the effects of various instructional designs (for an overview, see Mayer, 2014). Many of these studies aim to foster learning by providing a learning environment which facilitates learning by reducing extraneous cognitive load. In contrast, it sometimes may be more beneficial to make learning harder and more effortful. Making learning harder to reach better learning outcomes might sound unusual. Indeed, there are studies reporting such effects – naturally, not for all difficulties placed in the learning environment, but only for so-called desirable difficulties (Bjork, 1994). Nevertheless, even such desirable difficulties rely not only on diligent learners – a learner´s characteristic Abigail Adams (1764) calls for – but also on further learner´s characteristics which not only enable the learner to deal but also to profit from these difficulties. However, if the learner needs to fulfil specific criteria to profit from such difficulties, educators need to carefully match learners and specific instructional designs. Given the fact that an educator potentially needs to prepare different presentations of the same learning content, it becomes obvious that instructional manipulations which can be implemented easily may be preferred. One desirable difficulty, which is easy to manipulate, is to present visual text in a disfluent font (Bjork, 1994). This implementation is easy and time-efficient, because it only affects the surface of the text (Bjork, 1994).

Not only educators, but also learners sometimes impede their learning process, even though they might do this unintentionally. If you monitor students who prepare for exams, you can see that many of them listen to music while studying. Although students are probably not explicitly aware of this, the presence of background music might be an impeding factor for learning, because the music needs to be processed in addition to the learning material (Mayer & Moreno, 2003). Background music is a seductive detail (Rey, 2012), which in general seduce learners to turn their attention to them instead of the learning content. However, seductive details such as listening to background music might also have a positive impact on the learning process, because they may raise the learner´s motivation to learn or adapt the learner´s affect positively (Husain, Thompson, & Schellenberg, 2002; Rey, 2012).

The approaches of desirable difficulties and seductive details together lead to the question of which characteristics learners need to fulfil to be able to really learn better if difficulties are added to the learning environment: Either, because the educator decides to complicate learning by printing a text in a disfluent font or because learners themselves decide to listen to music while studying. Therefore, this dissertation aims for a better understanding of the effects of disfluency and background music in interaction with relevant learner´s characteristics.

2 Theoretical Background

To identify such relevant learner´s characteristics, it is first important to understand how learning material is processed depending on its characteristics. Learning material can be presented in many different ways. In general, one can differentiate between information presented in different modalities (mainly auditory and visual in academic learning) or different codes (text or pictures; Mayer, 2014). Different models and theories describe, how the processing of learning material differs mainly depending on these two characteristics.

2.1 Cognitive Information Processing

Two of the most prominent approaches to describe the processing of text and pictures are the cognitive theory of multimedia learning (Mayer, 2005) and the integrated model of text and picture comprehension (Schnotz & Bannert, 2003) which are discussed in the following.

Mayer´s (2005) theory differentiates between three different memory systems: sensory memory, working memory and long-term memory. Moreover, it describes three important different cognitive processes, namely selection, organization, and integration as well as three general assumptions: the dual-channel assumption, the limited capacity assumption, and the active processing assumption. Finally, the cognitive theory of multimedia learning (Mayer, 2005) is based on two other approaches. Firstly, it is based on Baddeley´s (1986) assumptions of how working memory functions. Baddeley (1986) describes two different slave systems in working memory: Auditory information is processed with the phonological loop, while the visuospatial sketchpad is responsible for the processing of pictures. The same differentiation in different channels which are responsible for auditory and visual information can be found in Mayer´s (2005) model and is known as the dual-channel assumption. And secondly, Mayer´s (2005) theory is based on the dual-coding theory (Paivio, 1986). The dual-coding theory also refers to the presence of two different processing system. Moreover, it describes that text is processed with the verbal channel, while pictures are processed with pictorial and also with the verbal channel. This is why pictures are dual-coded and therefore, they are remembered better.

All these assumptions and approaches are combined in Mayer´s (2005) cognitive theory of multimedia learning. According to this theory, learners first need to select important visual or auditory information out of all presented information by turning attention to them. Furthermore, auditory information is in general processed with the auditory channel, which leads to sounds in working memory, while visual information is processed with the visual channel, which leads to images in working memory (dual-channel assumption). The capacity in each channel is limited (limited capacity assumption). However, it is possible that information is represented in both channels. For example, reading a text first claims the visual channel, while an experienced reader would meanwhile transfer the written words into sounds that are processed with the auditory channel. The aim of the active processing of sounds and images is to organize them into coherent verbal or pictorial models. As a last step, learners need to actively build one coherent mental model which includes information of both models (active processing assumption). For building an efficient model it is also important that learners integrate prior knowledge into it, which is stored in long-term memory.

Mayer (2005) remains rather vague when talking about the different levels of processing. He only differs between essential processing, which results in a mental representation of the learning content, and generative processing, which aims at making sense of the learning content. However, for these two processes, Mayer (2005) neither differentiates between representations in different codes nor between different modalities, but assumes a parallel processing of all representations.

Schnotz and Bannert (2003) disagree with the assumption of parallel processes for all representations. Their integrated model of text and picture comprehension (Schnotz & Bannert, 2003) postulates that different codes are processed differently. According to their model, the processing of text, independent of its modality, proceeds in three different steps: Firstly, the learner subsemantically processes only the surface of a text, which leads to a text surface representation. Secondly, a semantic processing takes place, and the learner builds propositional representations of the text. Thirdly, a mental model is constructed in which also prior knowledge is integrated. Comparable to these levels of text processing, a learner develops different levels of learning outcomes (Schnotz & Bannert, 2003): A text surface representation enables a learner to answer simple recall questions, where information of the text only needs to be recalled without any comprehension of the content. To answer comprehension questions, a learner also needs to have processed the text semantically. For higher levels of learning outcomes, the construction of a mental model is needed.

Besides the processing of text, Schnotz and Bannert (2003) also describe the processing of pictures: After the perception of a picture, a visual image is created. Already in the second step of processing, this image becomes thematically selected and integrated in the mental model. Thus, in this model, the processing of pictures is not parallel to the processing of text.

To conclude, both Mayer´s (2005) cognitive theory of multimedia learning and Schnotz and Bannert´s (2003) integrated model of text and picture comprehension describe the processing of information presented in different representational codes. Mayer (2005) focusses more on the differentiation in processing in different memory systems and also considers different modalities, while he assumes parallel processes for all representation formats. Thus, he postulates two coherent mental models (verbal and pictorial), which then need to be mapped into one integrated model together with prior knowledge. In contrast to Mayer (2005), Schnotz and Bannert (2003) postulate different, non-parallel processes for different representational codes, as text need one additional step of processing in comparison to the processing of pictures. Moreover, they assume only one coherent mental model in which the information of both representational codes is integrated.

The question of whether there are two mental models or only one becomes relevant when learning with a multimedia learning environment, where text and picture normally represent the same content in different representational codes. Schüler, Arndt, and Scheiter (2015) created a task where learners learned a combination of text and pictures which both either depicted general or specific information about the same topic (e.g. table vs. desk). Results indicated that general sentence information were integrated with specific picture information, because learners falsely meant to recognize a specific sentence after they had learned a general sentence together with a specific picture. Schüler et al. (2015) argue that this underlines the assumption of only one integrated coherent mental model. In contrast, no such effect was found for the combination of general pictures and specific sentences: In this case, learners were able to remember the general pictures correctly, independently of the presence of a general or a specific sentence. This speaks against the view of only one integrated mental model at the first glance (Schüler et al., 2015). However, Schüler et al. (2015) used a recognition task, and thus, they assume that learners may have relied on a perceptually-based representation of the pictures instead of a mental model. If this was the case, results would not contradict the assumption of one single, integrated mental model. All in all, the assumption of only one integrated mental model seems to be more plausible compared to the assumption of two independent mental models.

2.2 Cognitive Load Theory

The processing of both text and pictures leads to cognitive load. The cognitive load theory (Chandler & Sweller, 1991; Kalyuga, 2011; Sweller, Ayres, & Kalyuga, 2011; Sweller, Van Merrienboer, & Paas, 1998) describes that different aspects of the learning material cause different types of load.

In the beginning, the traditional cognitive load theory (Sweller et al., 1998) described three separate kinds of cognitive load: Firstly, intrinsic cognitive load, which is mainly influenced by the complexity of the element interactivity, i.e. the number of different elements a learner needs to process in parallel. Thus, intrinsic cognitive load depends on the learning task per se and not on the instructional design of the learning phase. Moreover, intrinsic cognitive load also depends on the level of prior knowledge a learner has. With increasing prior knowledge, a learner can build chunks which consist of different elements. This leads to a reduced number of chunks an expert needs to process compared to a novice who needs to process all single elements. Secondly, germane cognitive load, which refers to the learner´s engagement in schema construction. This load reflects all activities from the learner which contribute to learning. And thirdly, extraneous cognitive load, which reflects the instructional design of the learning task (see also Chandler & Sweller, 1991). Extraneous cognitive load includes all cognitive resources needed from the learner which are extraneous for the learning content. Thus, this type of load is easy to manipulate because it mainly depends on the instructional design of a learning material. Importantly, it is not only the design of the learning material per se, but also the question of how good it fits to the characteristics of the learner (expertise reversal effect; Kalyuga, Ayres, Chandler, & Sweller, 2003). According to cognitive load theory (Chandler & Sweller, 1991), extraneous cognitive load should be held as small as possible to not overburden working memory capacity.

Later on, it was questioned whether the differentiation in three different types of cognitive load is applicable. Sweller et al. (2011) recommended to differentiate only between intrinsic and extraneous cognitive load, because only these two types of load are imposed by the learning material. Furthermore, they suggest speaking of germane resources instead of germane cognitive load, because this concept refers to the resources in working memory which “are devoted to information that is relevant or germane to learning” (p.57), which refers to intrinsic cognitive load. Moreover, extraneous resources need to deal with extraneous cognitive load. Likewise Sweller et al. (2011) recommend holding extraneous cognitive load and the concerning needed working memory resources as small as possible. Comparable to Sweller et al. (2011), also Kalyuga (2011) contrasted “bad” load which arises from extraneous activities and are not relevant to learning to “good” load, which includes intrinsic and germane load (p.3). Moreover, he postulated that germane and intrinsic cognitive load are interdependent as they both contribute to schema acquisition. However, even though intrinsic and germane cognitive load might be interlinked, they still have different characteristics. Intrinsic cognitive load is a passive load which depends on the task affordance which is externally given, while germane cognitive load needs to be actively invested by the learner (Seufert, 2018). Thus, to understand the effects of different instructional designs, it is necessary to differentiate between both concepts. Moreover, this should be independent of the name: germane cognitive load or germane resources.

In summary, cognitive load theory postulates that instructional designers should minimize extraneous cognitive load in order to have enough free capacities to invest in germane processes. On the contrary, there are two different approaches reporting better learning outcomes for instructional interventions which raise extraneous cognitive load: so-called desirable difficulties (such as disfluent fonts) and seductive details (such as background music).

2.3 Desirable Difficulties and the Example of Disfluency

“Desirable difficulties […] are desirable because they trigger encoding and retrieval processes that support learning.” (Bjork & Bjork, 2011, p. 58). Thus, they are difficulties placed in the learning process on purpose to make the processing of the learning content more active (Bjork, 1994). Learners can process the learning content with two different systems (James, 1890/1950): System 1 processes rather quickly, intuitively and effortlessly, while the processing with system 2 is more effortful and slower, but also more analytic and deliberate. One characteristic which is responsible for the activation of one specific system is the perceived, subjective difficulty of the learning content (Alter, Oppenheimer, Epley, & Eyre, 2007): Learning material which is perceived as more difficult has a better chance to activate system 2. This leads to a deeper processing, to a better metacognitive regulation that increases the application of cognitive resources (Alter et al., 2007) and thereby to better learning outcomes. However, it is important to increase only the subjective, not the objective difficulty of a learning task (Bjork, 2013).

One prominent example for a desirable difficulty that modifies the usual learning condition is to manipulate the fluency of a visual text, i.e., to present the text in a disfluent font (Alter et al., 2007). This is one comparably easy way to implement a desirable difficulty, as it only affects the surface of a text. The so-called disfluency effect postulates better learning outcomes after learning texts written in a font that is harder to read, such as Haettenschweiler, compared to usual fonts, such as Arial (Diemand-Yauman, Oppenheimer, & Vaughan, 2011; Eitel, Kühl, Scheiter, & Gerjets, 2014 (Experiment 1); French et al. 2013; Sungkhasettee, Friedman, & Castel, 2011). Harder to read fonts raise the perceived difficulty of the text, thereby increasing extraneous cognitive load (Eitel et al., 2014). However, the objective difficulty and thereby intrinsic cognitive load is not impaired by the font fluency. Eitel et al. (2014) argue that disfluent fonts would also not impact germane cognitive load, because learners do not have to actively generate new information. However, germane cognitive load can also be defined by the resources which are devoted to the acquisition of schemata (Paas, Renkl, & Sweller, 2003; Sweller et al., 2011). Thus, according to this definition, the processing with system 2 activated through the presence of disfluency might be reflected in an increase in germane cognitive load. Seufert, Wagner, and Westphal (2017) also argue, that disfluency is a metacognitive cue which motivates the learner to invest a higher amount of mental effort and to be more engaged in the learning process. Therefore, the question of whether disfluency has an impact on germane cognitive load mainly depends on the conceptualisation of germane cognitive load and an equivalent formulation of the items which measure germane cognitive load.

This leads to the question of how the font fluency affects the processing of text. The additional extraneous cognitive load of disfluent fonts on working memory is caused by the raised difficulty to encode the surface of the visual text (Eitel et al., 2014). With regard to Mayer´s (2005) cognitive theory of multimedia learning, this additional load is posed in the visual channel which has an impact on the creation of mental images and the following organization of both the pictorial model and the final, integrated mental model. Moreover, it is interesting to consider which levels of processing and learning outcomes are affected by disfluent fonts. In Schnotz and Bannert´s (2003) integrated model of text and picture comprehension, disfluent fonts would impede the construction of a text surface representation. This sub-semantic process is necessary to recall a text (Schnotz & Bannert, 2003). In addition, all further steps of processing are affected by disfluency: The semantic processing of the text resulting in propositional representations is affected as well as the construction of a coherent mental model (see Schnotz & Bannert, 2003). These higher levels of processing are necessary to answer questions which measure higher levels of learning outcomes, such as comprehension or transfer tasks (see Schnotz & Bannert, 2003).

Empirically, the implementation of disfluency led to different results. There are studies reporting a positive effect (Diemand-Yauman et., 2011; Eitel et al., 2014 (Experiment 1); French et al. 2013; Sungkhasettee et al., 2011) besides studies reporting no main effect (Song & Schwarz, 2008; Guenther, 2012; Meyer et al., 2015; Rummer, Schweppe, Schwede, 2016; Yue, Castel, & Bjork, 2013 [Experiments 2b and 3] or even a negative impact (Katzir, Hershko, & Halamish, 2013; Yue et al., 2013 [Experiments 1a and 2]) of disfluency on learning. One possibility to explain these varying results is to consider specific learner´s characteristics as they might have been represented differently in the different studies. Bjork and Bjork (2011) emphasise that learners need to fulfil specific criteria to deal with desirable difficulties in general. Otherwise, they hinder learning and become undesirable (Bjork & Bjork, 2011). The probably most relevant of these crucial learner´s characteristics is the learner´s working memory capacity. Working memory capacity needs to be high enough to compensate for the additional cognitive burden coming along with disfluent fonts. Only if working memory is high enough, there is still enough capacity left for a deeper processing and metacognitive regulation processes.

To sum up, printing text in a disfluent font is a desirable difficulty which is easy to implement but empirically controversially discussed. Learners need to have a sufficiently high working memory capacity to be able to profit from disfluency. Particularly the creation of a text surface representation and thereby learners´ recall performance is affected by different font fluencies. Moreover, as further steps of processing rely on this representation, it might also impact comprehension or transfer of the learning content.

2.4 Seductive Details and the Example of Background Music

Besides desirable difficulties, also seductive details are discussed to foster the learning process even though they are also known to pose an additional load in working memory (Rey, 2012). Seductive details are potentially interesting and attractive information which are added to the learning material to raise the learner´s interest in the learning environment (Harp & Mayer, 1998). However, seductive details seem to raise the emotional, but not the cognitive interest in a learning environment (Harp & Mayer, 1998). Typically, seductive details are presented as pictures (e.g., Harp & Mayer, 1998), additional text (e.g., Garner, Gillingham, & White, 1989; Harp & Mayer, 1998; Park, Flowerday, & Brünken, 2015), or background music (Grice & Hughes, 2009; Lehmann & Seufert, 2017a; Mayer & Fiorella, 2014; Moreno & Mayer, 2000). Seductive details are unnecessary for the learning content (Garner et al., 1989; Mayer & Fiorella, 2014). Thus, they pose an additional cognitive load in working memory, reflected in extraneous cognitive load, which is thereby not available for the processing of the actual learning content (Rey, 2012). Furthermore, they distract the learner from the actual learning content and may activate inadequate schemata (Harp & Mayer, 1998). Otherwise, learners need to actively ignore them, which also causes extraneous cognitive load (Sanchez & Wiley, 2006). All in all, the seductive detail effect describes a negative impact of seductive details on learning.

Particularly background music is one kind of seductive detail that many learners add to their learning environment unreflectively. Obviously, learners listen to music while learning with the idea to foster their learning process, for example through a raised motivation to learn. Even though background music may raise the interest in a learning environment, this would lead to only emotional, not cognitive interest (Harp & Mayer, 1998). Cognitive interest, i.e. the satisfaction of understanding the learning content, would be much more relevant to foster learning (Harp & Mayer, 1998). However, an increased motivation to learn may be reflected in an increased germane cognitive load, which may foster learning (Paas et al., 2003).

In short, the presence of background music may increase extraneous or germane cognitive load, which burdens working memory. This leads to the question of how music is processed in working memory. According to Mayer´s (2005) model, music as auditory information is processed within the auditory channel, even though Mayer (2005) does not mention music explicitly, but speaks about auditory information in general. However, other researchers assume an independent subsystem for the processing of music: For example, Berz (1995) postulates a model of working memory that is based on Baddeley´s (1986) model, but includes another subsystem that is used for processing music. There is also empirical evidence for this theoretical assumption: In a study by Rowe, Philipchalk, and Cake (1974) it was tested whether participants could recall words and sounds differently well, depending on the type of distraction presented in a shadowing phase after the learning phase. Participants showed better results for the recall of words after being distracted by sounds and vice versa. If words and sounds were both processed within the phonological loop, they would have been equally distracting. Thus, the idea of an independent subsystem that is responsible for music is supported. This idea was also taken up and strengthened by further authors (e.g. Deutsch, 1970; Paivio, Philipchalk, & Rowe, 1975; Rowe, 2013; Salamé & Baddeley, 1989).

The question of whether music is processed with one of the two subsystems being responsible for the processing of text or with an independent one becomes even more important when considering that the learner´s working memory capacity is limited (e.g. Mayer, 2005). If there is another system responsible for the processing of music, the additional arising load posed by background music would be less harmful compared to the assumption, that background music is processed within the auditory channel. Moreover, auditory information such as background music is always processed before visual information (Salamé & Baddeley, 1989). Thus, if the learner does not have enough capacity, background music would be processed at the expense of processing the actual learning content.

A further question of interest is which levels of processing will be affected by the presence of background music. Unfortunately, Schnotz and Bannert´s (2003) model does not include the differentiation in visual and auditory information. If background music is processed at the expense of the learning content (Salamé & Baddeley, 1989) one could carefully argue that all levels of processing will be affected, because less cognitive capacity is available. Moreover, when speaking about learning outcomes, one might argue that higher levels of learning outcomes are even more affected: They require more cognitive capacity because more information units need to be combined (see Bloom´s Taxonomy, 1956). Consequently, if the same capacity is already burdened by background music, less capacity is left for these processes. Thus, comprehension or transfer performance should be more impaired by the presence of background music than recall performance.

Concerning the empirical results about the influence of seductive details in general, there is a meta-analysis which reveals an overall negative impact on learning outcomes (Rey, 2012). The same holds true for studies investigating the impact of background music: A meta-analysis (Kämpfe, Sedlmeier, & Renkewitz, 2010) reported an overall negative impact of listening to music while learning on learning outcomes. Nevertheless, there are also studies reporting a positive (e.g., de Groot, 2006; Hallam, Price, & Katsarou, 2002 [Experiment 1]; Kang & Williamson, 2014; Savan 1999), or no (Grice & Hughes, 2009; Jäncke & Sandmann, 2010) influence of background music on learning outcomes.

Thus, comparable to the impact of disfluency on learning, there seem to be further learner´s characteristics which might help to explain these varying results. In order to compensate for the disadvantages of adding seductive details, the learner´s working memory capacity needs to be high enough to process the increased extraneous cognitive load arising from the presence of background music (or seductive details in general) in addition to the learning content. Only then, there is a chance that seductive details may have a beneficial effect on learning outcomes. Moreover, there are different possible mediators which explain the positive influence of seductive details on learning. Potential mediators may be a learning supportive mood, increased interest or higher motivation in general, which thereby increases germane cognitive load (Paas et al., 2003).

2.5 Desirable Difficulties and Seductive Details – Similarities and Differences

When comparing desirable difficulties with seductive details in general or the disfluency effect with the seductive detail effect in specific, various similarities and differences show up. One difference becomes clear when considering how disfluent fonts and background music affect learning with regard to processing theories (e.g. Mayer, 2005). Disfluency has its impact directly on the processing of visual text, which burdens the visual channel. In contrast, background music affects the processing of visual text one step later, when the text becomes transferred into sounds, which takes place in the auditory channel. However, in both cases, sufficient working memory capacity is one crucial factor to compensate for the increased cognitive demands.

These increased cognitive demands arise because desirable difficulties as well as seductive details pose additional extraneous cognitive load in working memory (Eitel et al., 2014; Rey, 2012). However, the perceived difficulty between the two interventions might differ, even though there are, to my knowledge, no studies investigating this difference. Alter et al. (2007) report a higher perceived difficulty of disfluent compared to fluent fonts, meaning that a learner would score the learning environment as more exhausting. In contrary, many learners choose to add music to their learning environments on their own. As they probably do this with the intention to foster learning, this would speak against a higher perceived difficulty, meaning that learners are potentially not aware of the additional load arising while listening to background music. Maybe this additional load becomes overcompensated by an increased motivation to learn and an increased emotional interest in the learning environment. Both manipulations may have a positive impact on learning outcomes at the same time. The theoretical foundation of this positive impact differs between desirable difficulties (deeper processing) and seductive details (increased motivation). Both, a deeper processing as well as an increased motivation, might potentially be reflected in an increased germane cognitive load.

Besides the increased germane load, one further similarity between desirable difficulties and seductive details is the huge variance in empirical results. Thus, it becomes obvious that it is not the intervention per se, but its interplay with specific learner´s characteristics which influences learning outcomes. Therefore, to explain the influence of background music as well as of disfluent fonts, it seems to be crucial to consider further variables, such as the learner´s working memory capacity, but also the learner´s interest and motivation to learn. In Mayer´s (2005) theory, concepts like a raised interest in the learning environment only play a minor role. However, Moreno (2006) complemented Mayer´s (2005) model with such affective variables and called it the cognitive-affective theory of learning with media, which might help identify relevant learner´s characteristics.

2.6 Cognitive-Affective Theory of Learning with Media

The basic structure of Moreno´s (2006) model strongly reminds of Mayer´s (2005) model. However, she added three additional types of instructional media (manipulatives virtual gloves, smells, and flavours) and the according sensory memory (tactile, olfactory, and gustatory) to the cognitive theory of multimedia learning (Mayer, 2005) that only deals with texts and pictures and an according auditory and a visual channel. Furthermore, and more importantly at this point, Moreno (2006) added individual differences of the learner to the model. She points out, that learner´s characteristics such as prior knowledge (e.g. Kalyuga et al., 2003; Seufert, 2003) or modality preferences (Plass, Chun, Mayer, & Leutner, 1998) are important to consider while designing a learning environment. Besides pointing out the importance of these moderating aptitudes, Moreno (2006) also stated the affective and metacognitive mediation assumptions. The affective mediation assumption assumes that motivational and emotional factors may mediate the learning progress by being affected by the instructional design in the beginning and then having an impact on cognitive engagement. The same may hold true for metacognitive processes such as monitoring, controlling and adapting cognitive processes.

All in all, Moreno (2006) does not disagree with any of Mayer´s (2005) ideas. She only pointed out the idea, that processing may differ between different learners due to their learner´s characteristics. However, she did not postulate any clear assumptions how learners´ characteristics may influence information processing, but called for studies investigating this relation. That is one reason why several studies in the following years focussed on the influence of motivational (Magner, Schwonke, Aleven, Popescu, & Renkl, 2014) and affective states (Plass, Heidig, Hayward, Homer, & Um,

2014) on learning as well as on specific learner´s characteristics such as prior knowledge (Kalyuga, 2008), or working memory capacity (Dutke & Rinck, 2006) besides many other potential aptitude variables.

2.7 Learner´s Characteristics as Aptitude Variables

However, Moreno (2006) was not the first who made aware of the potential to consider learner´s characteristics. This is also postulated in the aptitude-treatment-interaction approach (Snow, 1989), which assumes that with varying aptitude variables, the impact of the instructional design of a learning environment on learning outcomes changes. According to Hasselhorn and Gold (2013), learner´s characteristics, which might be considered as potential aptitudes, can be clustered into two groups, cognitive and motivational-volitional variables. Cognitive factors include inter alia prior knowledge, working memory capacity or metacognitive strategies. Motivational-volitional factors include affective variables such as mood while learning or motivational facets such as interest among others. However, there are also further learner´s characteristics which expand the two clusters of Hasselhorn and Gold (2013). For example, personality traits, such as the learner´s extraversion, whose importance in the context of learning was shown in different studies (e.g. Ackerman & Heggestad, 1997; Chamorro-Premuzic & Furnham, 2008).

Besides the differentiation into different content-related clusters, there are also further relations into which aptitudes can be grouped. For example, one can differentiate between mainly stable factors (traits) and situational variable factors (states) (Steyer, Schmitt, & Eid, 1999). Traits, such as the leaner´s working memory capacity, can be measured and considered for the design of a learning environment. However, states, such as the learner´s affect, allow the instructional designer to have an impact on them by manipulating the instructional design with the aim to foster learning.

Furthermore, two different functions of aptitudes can be differentiated: On the one hand, there are specific learner´s characteristics which may compensate for poor designs. On the other hand, there are aptitudes which may be required to enhance the positive effect of an instructional design.

Originally, these so-called ability-as-compensator and the ability-as-enhancer hypotheses were established by Mayer and Sims (1994) in relation to the processing of pictures and animations. However, both approaches may also be transferred to other aptitude variables in combination with other instructional factors.

Ability-as-compensator. As potentially compensating variables, all aptitudes might be considered which compensate for the difficulties arising from badly designed learning environments. This means, that firstly, learners with a sufficiently high aptitude would perform equally well regardless of whether they learn with good or poor learning material. Secondly, the same poorly designed learning material would impair the learning process of learners with a lower aptitude score (see Table 1).

Table 1

Ability-as-compensator hypothesis

	Well designed learning environment	Poorly designed learning environment
Ability sufficiently high	o	o
Ability not sufficiently high	o	-

Note. o normal learning outcomes, - worse learning outcomes.

Ability-as-enhancer. On the contrary, there are also learners´ characteristics which raise the learning outcome when combined with a specific instructional design. Such enhancers enable the learner to profit from instructional interventions, while learners without this ability learn equally well, independent of the presence of specific interventions (see Table 2).

Table 2

Ability-as-enhancer hypothesis

	Instructional intervention present	Instructional intervention not present
Ability sufficiently high	+	o
Ability not sufficiently high	o	o

Note. + better learning outcomes, o normal learning outcomes.

2.8 Aptitude-Treatment Interactions

As a next step, it is necessary to identify and classify relevant aptitudes in relation to desirable difficulties and particularly disfluent fonts as well as for seductive details and particularly the presence of background music. As already discussed above, both interventions pose additional load in working memory which needs to be processed by the learner. Thus, the relevance of the learner´s working memory capacity in order to compensate for this additional cognitive burden was already outlined above.

2.8.1 Working Memory Capacity

Working memory capacity describes the amount of information that can be dealt with simultaneously (Cowan, 2012). Various authors (Cowan, 2001, 2012; Mayer, 2005; Miller, 1994; Moreno, 2006) point out that this capacity is limited and varies between different learners. On average, learners can store 7±2 information (Miller, 1994) or process about 4 information at the same time (Cowan, 2001). Working memory capacity is comparably stable (Waters & Caplan, 2003) and can thereby be defined as a trait variable. With this capacity, all three types of cognitive load need to be processed: intrinsic, germane and extraneous cognitive load.

When talking about the use of desirable difficulties such as disfluent fonts on the one hand, working memory firstly needs to compensate for the additionally arising cognitive burden. Thus, as a first step, working memory capacity functions as a compensator for the increased extraneous cognitive load. As a second step, if the learner has enough capacity left, desirable difficulties lead to deeper processing. This leads to better learning outcomes but may also burden working memory – even though this load might be reflected in germane processes, depending on the definition. Therefore, working memory capacity can also be considered as an enhancer for desirable difficulties (see Figure 1).

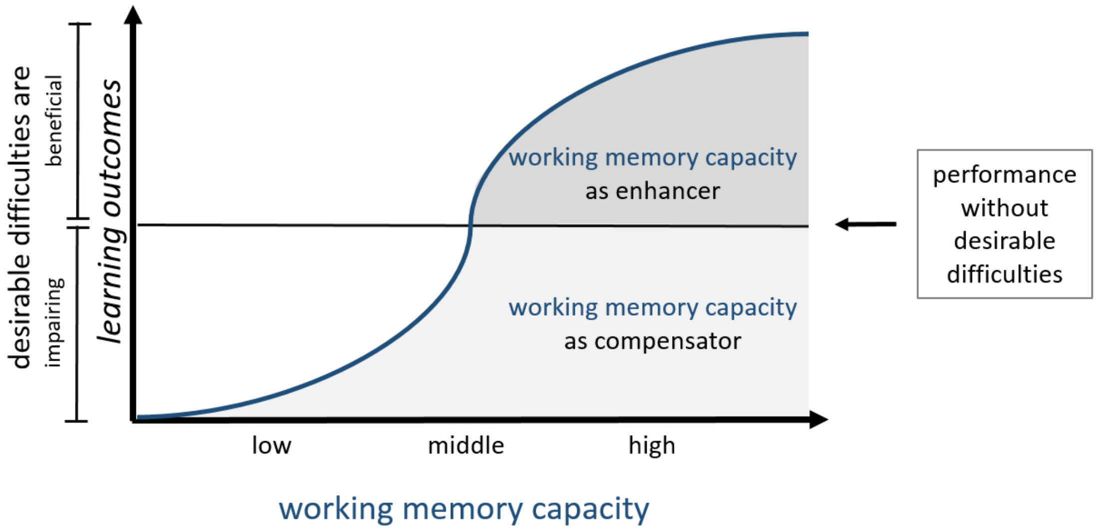

Figure 1. Effect of desirable difficulties with varying working memory capacity on learning outcomes.

Figure 1 also depicts the relation between learning outcomes when learning without desirable difficulties and working memory capacity, reflected in the black line. Naturally, it is also possible that learning outcomes constantly raise with higher working memory capacity which depends on the learning content: If the learning task requires the learner to process many information at the same time or if the task requires a high attentional control, a higher working memory capacity would benefit learning outcomes (Miyake & Shah, 1999). If this is the case, the line would constantly raise with higher working memory capacity.

On the other hand, when talking about seductive details such as background music, the function of working memory capacity is slightly different. Comparable to the model above, the learner´s working memory is burdened: Either from processing the additionally induced cognitive load (Park, Moreno, Seufert, & Brünken, 2011) or from the attempt to ignore the presented seductive details (Sanchez & Wiley, 2006). Again, sufficiently high working memory capacity needs to compensate for this load leading to the function of working memory capacity as a compensator. In contrast to desirable difficulties, working memory capacity does not function as an enhancer for seductive details, because the presence of seductive details does not urge the learner to make use of this capacity. Besides the amount of working memory capacity, also the learner´s prior knowledge might play an important role while compensating for poor instructional design.

2.8.2 Prior Knowledge

Of all learner's characteristics, prior knowledge is probably the most considered and various authors point out the importance of carefully considering it while designing a learning environment (e.g. Kalyuga, 2008; Kalyuga et al., 2003; Seufert, 2003). Prior knowledge enables the learner to build chunks (Van Gog, Ericsson, Rikers, & Paas, 2005). Thus, the learner needs to process less but more comprehensive information units compared to a novice (Van Gog et al., 2005). Moreover, new information about the learning content can be integrated into already consisting schemata (Van Gog et al., 2005), thereby easing the construction of a mental model. All this leads to a decrease in intrinsic cognitive load (Gerjets, Scheiter, & Catrambone, 2004) and thus, to less burden in working memory. Therefore, if prior knowledge disburdens working memory capacity, its effect on learning with desirable difficulties and seductive details could be equally considered as the effect of working memory capacity: Prior knowledge might have a compensating effect for both interventions which is mediated by a disburdened working memory. Moreover, it is also possible that prior knowledge leads to a higher interest in the learning material (Tobias, 1994). Higher interest and with this, higher motivation, may also have a positive influence on germane cognitive load (Paas et al., 2003)

It is difficult to classify prior knowledge as a state or a trait variable. Of course, knowledge about a specific topic varies a lot, which is basically the aim of every learning environment. Thus, knowledge is not stable and can therefore be considered as a state variable. However, the knowledge learners already have before they begin to learn a specific content cannot be easily manipulated by the learning environment, with the only exception of a pre-training phase (Mayer, Mathias, & Wetzell, 2002). If there is no pre-training phase implemented, prior knowledge before learning can be considered as a moderating trait variable.

While the impact of desirable difficulties seems to be well explained through the two cognitive aptitudes working memory capacity and potentially also prior knowledge, seductive details also rely on the effect of further motivational and affective variables (Rey, 2012) as well as on personality traits (Avila, Furnham, & McClelland, 2011).

2.8.3 Arousal and Extraversion

Particularly when talking about the influence of background music, Husain et al. (2002) postulate, that it is not the presence of background music itself that has an influence on learning outcomes, but rather the impact on the learner´s mood and arousal level, which again influences learning. In general, fast rhythms seem to raise the listener´s arousal, while slow rhythms seem to reduce the arousal level (Thompson, Schellenberg, & Letnic, 2011). Therefore, it becomes clear that arousal is a state variable, which can be influenced by the instructional designer. However, there is no such thing as the optimal arousal level, but the induced arousal needs to match the learner´s extraversion level (Eysenck, 1967, 1994; Eysenck & Eysenck, 1985): The higher the learner´s extraversion level, the higher the preferred arousal and vice versa. If the induced arousal matches to the learner´s extraversion level, learning performance may potentially be increased through the presence of background music. Extraversion is comparably stable over time (Roberts & DelVecchio, 2000) and is therefore a trait variable which should be taken into account as a potential moderating aptitude. Compared to extraversion, the learner´s arousal level is easier to manipulate and therefore a state variable. Thus, arousal should not be considered as a moderating, but as a mediating variable.

2.8.4 Mood

Moreover, besides arousal, listening to background music could also have an impact on the learner´s mood (Husain at al., 2002). Various authors (e.g. Goetz & Hall, 2013; Heuer & Reisberg, 2014; Pekrun, Lichtenfeld, Marsh, Murayama, & Goetz, 2017) point out the importance of affective variables on the learning process. Considering that seductive details can induce mood, Schneider, Dyrna, Meier, Beege, and Rey (2018) already found that the influence of seductive details depends on their emotional quality: While positively charged seductive details fostered learning, negatively charged seductive details hindered learning. However, there are also studies reporting that positive mood leads to a higher tendency to get distracted (Rowe, Hirsh, & Anderson, 2007) which is especially important while learning with seductive details as they tend to distract the learner from the actual learning content. Against the findings of Schneider et al. (2018), Kühl, Moersdorf, Römer, and Münzer (2019) did not detect any differences between positively and negatively affected seductive details. Thus, the relevance of mood still remains unclear. To further investigate the question about the relevance of mood as a potential mediator while learning with seductive details, mood should be considered as an aptitude variable in future research.

2.8.5 Motivation

Motivation is besides mood one further affective variable which seems to have a positive influence on the learning process (Vollmeyer & Rheinberg, 1998). Rheinberg, Vollmeyer, and Burns (2001) postulate different factors of motivation: interest, challenge, probability of success and anxiety, which all seem to predict learning. In general, higher motivation seems to lead to more engagement in the learning process, which is reflected by an increase in germane cognitive load (Paas et al., 2003).

The learner´s motivation to learn can be influenced by different variables, for example the interest in the learning content (Tobias, 1994). Furthermore, it might be influenced by the instructional design of the learning task (e.g. Abeysekera, Lakmal, & Dawson, 2015). Therefore, it is possible to manipulate the learner´s motivation by providing an appropriate learning environment. Thus, motivation can be classified as a state variable and should, therefore, be considered as a potential mediator while investigating the influence of different instructional designs on learning outcomes.

To sum up, to investigate the influence of seductive details on learning outcomes, different potential aptitudes need to be considered. First, working memory capacity, which needs to compensate for the additional induced load. And second, also motivational and affective factors need to be considered. They may function as an enhancer for learners with medium or higher levels working memory capacity. For learners with lower levels of working memory capacity, motivational and affective factors may at least help compensate for the additional extraneous load as learners may be higher engaged in the learning process. Thus, learners may profit from the presence of seductive details, but only if working memory capacity is high enough (see Figure 2). However, this relation needs to be questioned carefully, because seductive details do not automatically influence motivation and affect positively as demonstrated in the study by Kühl et al (2019). Thus, it is also possible that the additional arising load of seductive details needs to be compensated without any enhancing effects.

The green curve in Figure 2 represents learning outcomes in the case that seductive details are present and that these seductive details have a positive impact on motivational and affective learner´s variables. The blue curve represents learning outcomes from a cognitive point of view if seductive details have no influence on motivational and affective variables: In this case, seductive details only lead to an increased cognitive burden which needs to be compensated. Finally, the black line again represents learning outcomes if no seductive details are present. Similar to Figure 1, the black line as well as the horizontal part of the blue line may also increase constantly with increasing working memory capacity, depending on the characteristics of the learning content.

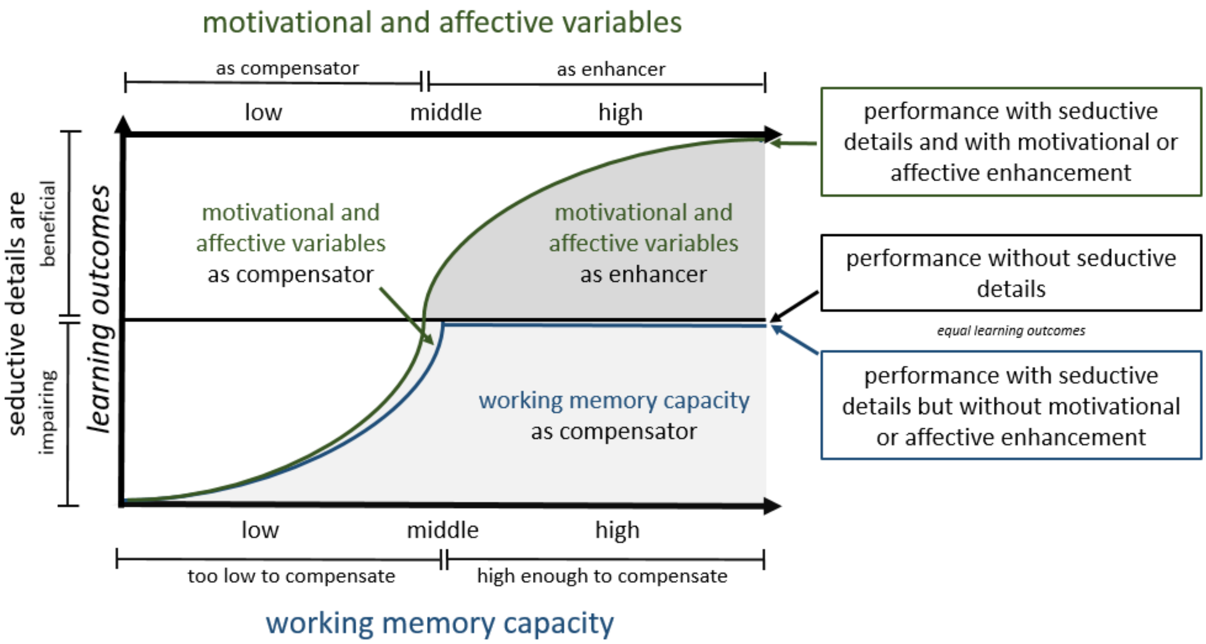

Figure 2. Additive effects of working memory capacity and motivational factors on learning outcomes in the presence of seductive details.

2.9 The Influence of Disfluent Fonts and Background Music on Learning

All in all, this dissertation investigates the question of whether it is possible to foster learning outcomes by adding desirable difficulties or seductive details to the learning material. Surface disfluency was chosen to represent desirable difficulties, as it is easy to manipulate and can thereby be used widely. Moreover, background music is used to represent seductive details in the following studies because many students listen to music while learning without a sufficient knowledge about its impact. In order to find and explain beneficial effects, different learner´s characteristics are considered as aptitudes, including cognitive (prior knowledge and working memory capacity), physiological (arousal), and affective factors (mood) as well as personality traits (extraversion).

To sum up all described approaches, they are brought together in one integrated model (see Figure 3). The structure of this model is adapted from Moreno´s (2006) and Mayer´s (2005) basic structure, but focusses only on components which are important for the following studies. Moreover, it includes all important aptitude variables to visualize where they affect learning outcomes.

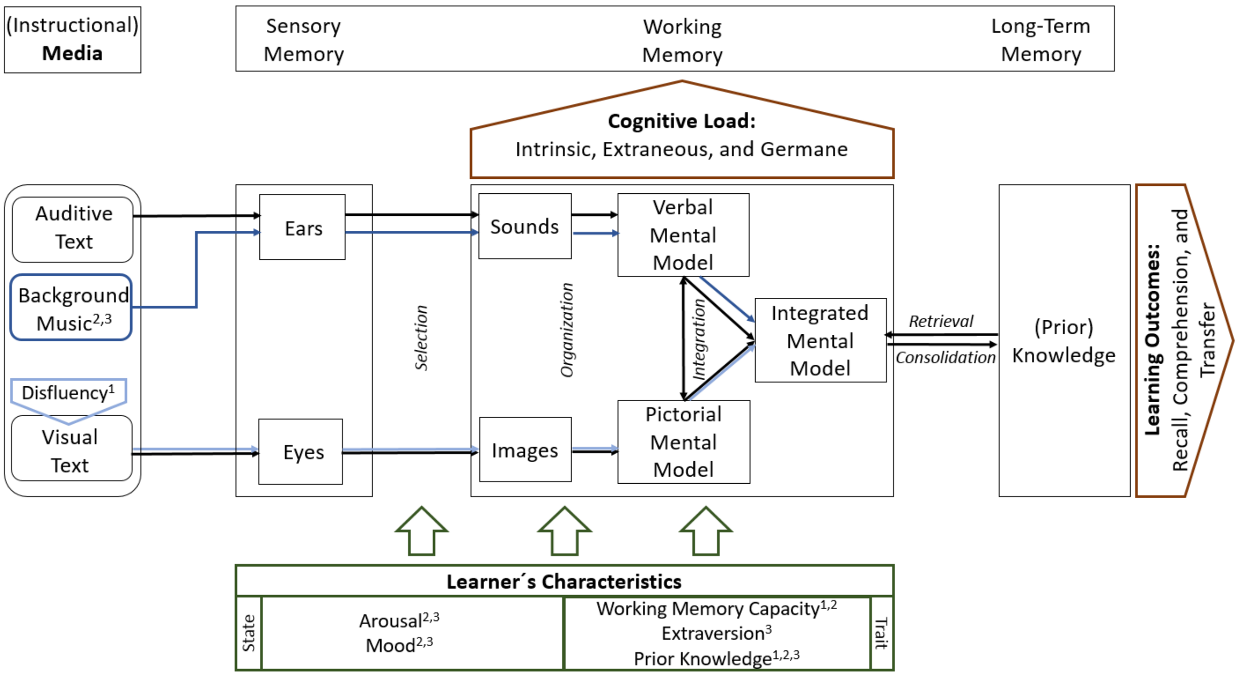

Figure 3. Cognitive-affective theory of learning text under consideration of disfluency, background music, and learner´s characteristics (Numbers indicate which of the following studies focusses on this component). Own representation based on Mayer (2005).

Disfluency can be implemented on the visual text, while it thereby affects the processing with the visual channel and has an impact on the creation of images as well as on the pictorial mental model. In contrast, background music is added to the learning environment as a new media which needs to be processed with the auditory channel. As a consequence, it impacts the representation of sounds in working memory. However, as we use instrumental background music without lyrics, there is no impact on the verbal mental model. Learner´s characteristics may have an impact on each step of processing: the selection process (e.g. if the learners´ working memory capacity is high enough, they will turn their attention to both background music and text), the organisation process (e.g. mood has an impact on the construction of coherent surface representations (Moreno, 2006)), as well as the integration into one coherent mental model (e.g. prior knowledge facilitates this process by providing already consisting schemata (Van Gog et al., 2005)).

3 Empirical Papers

The assumed interplays were investigated with three empirical studies which are presented in the following chapter. All three experiments are described more detailed in the concerning paper (see Appendix).

3.1 Study 1: "Working memory capacity and disfluency effect: An aptitude-treatment-interaction study" (Lehmann, Goussios, & Seufert, 2016)

3.1.1 Aim, Methods, and Results of Study 1

The first study investigates the interaction effect between the degree of font fluency (fluent or disfluent) of the learning material and the learner´s working memory capacity on learning outcomes and cognitive load. Under consideration of the introduced theoretical background, we assumed to find no main effect of disfluency, but an interaction effect between disfluency and working memory capacity for recall, comprehension and transfer performance: In the disfluency condition, test performance should be better the higher the learner´s working memory capacity. In the fluency condition, working memory capacity should not have an impact on learning outcomes. Concerning cognitive load, we assumed to find no effects on intrinsic load, but on extraneous cognitive load: Extraneous cognitive load should be higher after learning with disfluent learning material. In keeping with Eitel et al.´s (2014) argumentation, it was assumed that no impact on germane cognitive load would be detected.

We tested 47 students (M_{age} = 22.9, SD_{age} = 3.77; 85% females) with medium prior knowledge who learned a visual text. Half of them received the text printed in a fluent font (Arial), the other half received the same text printed in a disfluent font (**Haettenschweiler**). Working memory capacity was measured as a continuous aptitude variable. After the learning phase, recall, comprehension, transfer, and cognitive load were measured. Cognitive load was then measured again after the testing phase.

For recall, the two groups performed equally well. In the disfluency condition, working memory capacity influenced recall significantly: Participants with higher working memory capacity reached better recall scores. No influence of working memory capacity on recall was found in the fluency condition. The same pattern was found for comprehension: a significant interaction between condition (fluent, disfluent) and working memory capacity as well as a significant influence of working memory capacity in the disfluency, and no influence in the fluency condition. For transfer, the model showed no significant effects. Furthermore, the model showed no significant results regarding intrinsic, extraneous, and germane cognitive load after the learning as well as after the testing phase.

3.1.2 Discussion of Study 1

The results of study 1 partly support the assumptions which were made grounded on the introduced theoretical background. Increasing working memory capacity was needed to deal with disfluent fonts. Additionally, learning outcomes increased even further with increasing working memory capacity so that working memory capacity functioned not only as a compensator but also as an enhancer. This supports the model depicted in Figure 1, but only for recall and comprehension.

However, the use of disfluent fonts did not impact cognitive load, neither extraneous, nor germane cognitive load. This is especially unexpected, because we did find the expected interaction with working memory. What did working memory compensate for, if not extraneous cognitive load? Participants reported a small increase in extraneous cognitive load in the group which learned with disfluent learning material (52.1% versus 45.6%), however, this difference between the groups did not reach statistical significance. As already reported in the original paper (Lehmann et al., 2016) this might be due to the way the items are formulated, little motivation to learn, little interoceptive sensitivity, or also too insensitive Likert Scales (see also Lehmann, Hamm, & Seufert, 2018). Thus, the idea that disfluency induces cognitive load which can be called extraneous must not be dropped at this point but needs further investigation with a careful measuring.

Almost the same argumentation holds true when talking about germane cognitive load: No differences between the groups were detected by the cognitive load questionnaire (Klepsch, Schmitz, & Seufert, 2018). As described in the theory section, depending on the definition of germane cognitive load an impact of disfluency on germane cognitive load would be expected or not. The items in the used cognitive load questionnaire (Klepsch et al., 2017) do not focus on an active generation of new information but on the learners´ engagement to learn and the question if the learning material supports this engagement. Thus, a positive influence of disfluency on germane load could have been expected, but was, however, not detected. Nevertheless, results show better learning outcomes for learners with higher working memory in the disfluency condition. Thus, there are indeed positive effects of disfluency on learning which therefore, seem to be germane to the learning process. It might be the case that learners in the disfluency condition do not have the feeling of being supported, because the learning material looked rather deterrent and positive effects were rather unaware.

In conclusion, working memory capacity is a highly relevant aptitude variable while learning with disfluent texts as one example of desirable difficulties even though we do not completely understand the effects so far. Future research should aim at measuring other facets of extraneous and germane cognitive load and also an objective measuring method should be taken into account (e.g. Brünken, Plass, & Leutner, 2003).

Working memory was introduced to be not only a crucial variable for desirable difficulties, but also for seductive details because it may compensate for the additional cognitive load of both interventions. Thus, in a second study, a further look is taken at working memory capacity as a compensator for the increased extraneous cognitive load. In contrary to desirable difficulties, not working memory capacity but other factors such as the learner´s mood and arousal may be responsible for potential beneficial influence, which were therefore included in the design.

3.2 Study 2: „The Influence of Background Music on Learning in the Light of Different Theoretical Perspectives and the Role of Working Memory Capacity" (Lehmann & Seufert, 2017b)

3.2.1 Aim, Methods, and Results of Study 2

The second study deals with the interaction of background music and the learner´s working memory capacity on learning outcomes and the question of whether this interaction is mediated through arousal or mood. Besides other assumptions, we assumed to find a negative impact of background music when considered as a seductive detail only on comprehension for participants with lower working memory capacity. Moreover, we expected a better comprehension performance while listening to music for participants with higher working memory capacity, which should be mediated by arousal and mood.

We collected data from 81 participants (M_{age} = 21.46, SD_{age} = 4.30, 81.5% females) to test these assumptions. Participants had to learn a visual text, while randomly half of them were listening to instrumental background music. Working memory capacity was measured as a discrete aptitude variable. We measured recall and comprehension, as well as arousal and mood before and after learning.

As expected, we did not find any effects on recall, but on comprehension with prior knowledge as a significant control variable. For comprehension, we found a general advantage for the group which was not listening to background music. This influence was not mediated by arousal or mood, basically, because background music had no impact on arousal or mood. Moreover, by calculating contrasts between the groups with and without background music for each working memory capacity score, we found better comprehension outcomes in the group with a working memory capacity score of 2 for the participants who learned without background music. In addition, we found a linear trend for all participants who learned with background music: They performed better the higher their working memory capacity was. Overall, we did not find an advantage of listening to background music for any learner.

3.2.2 Discussion of Study 2 and the Overall Role of Working Memory Capacity

The aim of the presented study was to investigate the aptitude-treatment-interaction between working memory capacity as an aptitude and background music as a treatment variable. Comparable to study 1, we found a compensating effect of working memory capacity for the presence of background music: The presence of background music was only compensated by learners with higher capacity, resulting in equal results regardless of whether background music was present or not. Learners with a smaller working memory capacity were not able to compensate for the presence of background music, resulting in worse comprehension outcomes with background music present. Expectedly, but different to study 1, working memory capacity did not function as an enhancer for learners with higher working memory capacity scores. As discussed above, disfluent fonts should urge the learner to invest more effort in the processing of the learning material, even though we were not able to support this assumption by the measuring of an increased germane load. However, it is the working memory capacity itself whose complete use enables the learner to learn better with desirable difficulties present. The fact that participants do not always use their full potential of working memory capacity was already shown in different studies (e.g. Brose, Schmiedek, Lövdén, & Lindenberger, 2012; Brose, Schmiedek, Lövdén, Molenaar, & Lindenberger, 2010).

In contrast, the presence of background music should foster the learning process through increased affective components such as an optimized mood or an optimized arousal level as a physiological aspect (Husain et al., 2002). As we failed to induce arousal or mood by presenting background music, the role of the aptitudes in the learning process and therefore, the second theoretical model depicted in Figure 2 cannot be discussed adequately at this point. The manipulation of mood by adding seductive details already failed in a study from Kühl et al. (2019). Thus, there is future research needed to close this gap which is one aim of the third presented study.

Comparing the two studies, it becomes visible that working memory capacity was considered as a continuous variable in study 1, but as a discrete variable in study 2. Both approaches have theoretical foundations (for an overview, see Fukuda, Awh, & Vogel, 2010). However, the implemented assessment of working memory capacity (Oberauer, Süß, Schulze, Wilhelm, & Wittmann, 2000) reports discrete numbers of capacity. With this in mind, working memory capacity was considered as a discrete variable in study 2.

Working memory capacity is not the only relevant learner´s variable while investigating the impact on background music on the learning process. Furthermore, the learner´s extraversion level might play an important role because it determines the preferred arousal level. Moreover, to better understand the effects of background music on learning outcomes it might also be fruitful to measure its impact on cognitive load.

3.3 Study 3: "The Influence of Background Music on Learners with varying Extraversion: Seductive Detail or Beneficial Effect?" (Lehmann, Hamm, & Seufert, 2018)

3.3.1 Aim, Methods, and Results of Study 3

The third paper attempts to investigate the interaction effect between listening to background music and the learner´s extraversion level on learning outcomes and cognitive load. Considered as a seductive detail, we assumed that background music has an overall negative impact on learning outcomes. Moreover, we assumed an interaction between the presence of background music and the learner´s extraversion level: Extraversion should have an impact on learning outcomes, depending on whether the background music induces or reduces arousal. Regarding cognitive load, background music should raise extraneous and germane cognitive load.

To test our hypotheses, 167 students between 13 and 18 years (M_{age} = 14.38, SD_{age} = 1.00, 86% females) learned a visual text while randomly half of them were listening to a piece of instrumental Mozart music. Extraversion was considered as a continuous aptitude variable. We measured arousal before and after learning, as well as cognitive load, recall, comprehension, and transfer performance after the learning phase.

Results showed that background music only influenced transfer, but had no impact on recall or comprehension. Moreover, the influence of background music on transfer was unexpectedly positive: Learners with background music present performed better than those in the group without background music. In line with this, we only found an increased germane cognitive load in the group that learned with background music, but no influence on extraneous or intrinsic cognitive load. Prior knowledge was a significant control variable. Also against our expectations, background music did not influence the leaner´s arousal level. As a logical consequence, we did not find an interaction between background music and the learner´s extraversion level for recall, comprehension, and transfer.

3.3.2 Discussion of Study 3 and the Overall Role of Background Music

Study 3 aimed at a better understanding of the effects of background music on learning, inter alia by influencing the learner´s arousal level and by measuring the induced cognitive load. Compared to study 2, this time background music had a positive influence on the learning process, even though mainly comprehension was influenced in study 2 and mainly transfer was influenced in study 3. There is a huge number of possible reasons for this different effect: e.g. the studies included different learners with different learner´s characteristics, different learning material, and different music. The music in the third reported study shows different characteristics than the music in the second study, such as a different tempo and key. As Husain at al. (2002) already pointed out, the music´s characteristics are much more important for describing the influence of background music on the listener than the presence of music per se. Therefore, future research needs to systematically vary different music´s characteristics to better identify this pattern.

In study 3, cognitive load was measured in addition to learning outcomes. Interestingly, we did not find the expected impact of background music on extraneous cognitive load in the third study. The background music was not part of the learning material, thus, it should have led to an additional cognitive burden, finding reflection in an increased extraneous cognitive load. This was not the case. This issue is a point of further interest for future research: It is highly possible that different background music would indeed impact extraneous cognitive load, leading to different results. A similar effect was already discussed by Park et al. (2011) who found that seductive text and pictures impair learning differently depending on the load they induce.

In contrast, learners scored background music as germane, even though we did not detect the mediating variable. There was again no influence of background music on the learner´s arousal level but on learning outcomes. Therefore, the effects of how background music influences learning still remain unclear and the theoretical model depicted in Figure 2 can only partly be supported. Thus, Figure 4 depicts an adapted version of Figure 2, which only includes the components which were supported by the reported results: Increasing working memory functions as a compensator for the presence of background music. The positive impact of background music on transfer outcomes in study 3 might be explained by further variables, such as increased metacognitive processes. However, this requires further investigation and clarification and is therefore, not depicted in Figure 4.

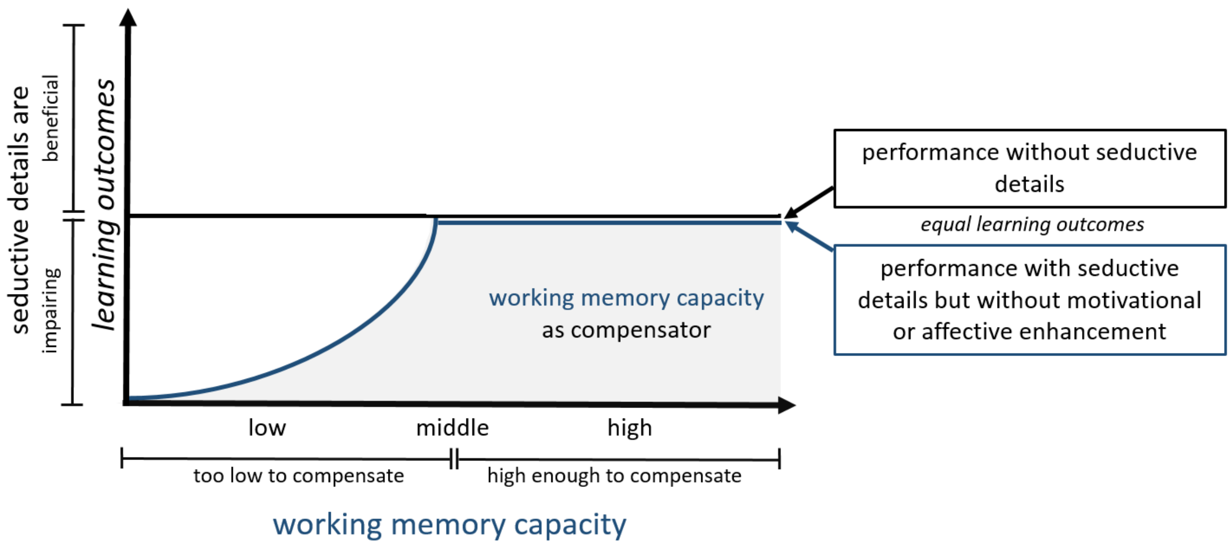

Figure 4. Effect of seductive details with varying working memory capacity on learning outcomes.

Concerning the processing of music, it also needs to be discussed how music is processed in working memory due to the results of the two reported studies. As described in the theory section, there are different opinions on whether music is processed within the phonological loop (see Baddeley, 1986) or within an independent subsystem (see for example Berz, 1995; Rowe et al., 1974). Considering the results of the second study, music cannot be processed completely independently in its own subsystem. If this were the case, listening to background music would not have had such a negative impact on learning in the second study. In contrast, the third study revealed a positive impact of background music together with no impact on extraneous cognitive load, speaking at least for more involved capacity when processing music. Therefore, it might be the case that music is not processed with the phonological loop, but with another subsystem which is embedded in the phonological loop. One could carefully assume that this subsystem increases the total amount of capacity to process all information, but also partly relies on the phonological loop. To test this assumption, one could implement another shadowing experiment such as Rowe and colleagues (1974), but include a third shadowing condition, namely pictures. If the phonological loop and the subsystem for music are independent, but intertwined systems that partly rely on the same capacity, presenting pictures in the shadowing phase would hinder recall of sounds less than presenting auditory text. Then again, presenting other sounds in the shadowing phase should be most harmful. Such an experiment would help investigate the mechanisms of working memory.

Finally, I would like to discuss the problem, that in the reported two studies about the effects of background music, we did not provide the possibility to our participants to choose songs they want to listen to on their own, but instead we chose the songs in advance. In a real learning scenario, learners can choose music depending on their preferences. However, it is not easily possible to implement this in an experimental scenario: If each participant brought his or her own favourite music, we would have received a large variety of genres, tempi, music with or without lyrics and in many different moods. This would have made it impossible to analyse the influence of the presence of music per se without any other mediating effects. One possible solution could be to provide a selection of different music pieces that are similar concerning all relevant characteristics. Participants would then have the chance to choose music which they like to listen while learning. This may also increase the chance to find a mediation effect of background music over mood on learning, as music the participants prefer may have a stronger positive impact on mood.

4 General Discussion

4.1 Theoretical and Methodological Implications

All in all, the reported three studies aimed at analysing which learner´s characteristics need to be considered for the decision of whether a disfluent font as one example for desirable difficulties or background music as one example for a seductive detail should be added to the learning environment.

Both manipulations have in common that they pose additional load in working memory: either by processing the additional information and/or, in case of background music, by an active regulation process to not get distracted but to focus on the learning content. However, in both studies where cognitive load was measured, no increase in extraneous cognitive load was detected. Nevertheless, working memory capacity was explicitly a crucial factor for learners in the experimental condition: With increasing working memory, the negative impact on learning outcomes of both disfluency and background music disappeared. The same increase in learning outcomes with higher working memory capacity was not detected in the control group. This speaks for an additional extraneous cognitive load, and thus, for a measuring problem. As already discussed, it might either be due to a too insensitive measurement (e.g. Lehmann et al., 2018) or to the way the items of the cognitive load questionnaire were formulated. As the formulation of the items is based on the conceptualisation of cognitive load, the reported results might be a first hint that this conceptualisation needs to be expanded to include further extraneous factors.

However, both manipulations have the potential to increase learning outcomes, as there are various studies which empirically found better learning outcomes in the experimental groups (e.g., Diemand-Yauman et al., 2011; de Groot, 2006; Kang & Williamson, 2014; Sungkhasettee et al., 2011). Thus, there seems to be some beneficial processes which are initiated. Only for background music, we detected an increase in germane load. For germane load in the disfluency study, no impact was found. The awareness of disfluency to be difficult seems to have an impact on the learners´ metacognitive processes (Alter et al., 2007; Weissgerber & Reinhard, 2017), even though it still remains unclear which phase of self-regulation exactly is impacted. It is possible that disfluency has an impact on the planning phase in a way that learners plan learning differently if they judge the learning material as difficult. This would possibly also lead to a different use of strategies and more monitoring. As a consequence, also the regulation process might be impacted by disfluency. Seufert (2018) describes that self-regulation causes cognitive load. Thus, it is more than plausible that the use of disfluent fonts would lead to an increase in germane load. It might be the same two reasons why we did not measure differences in extraneous cognitive load: The formulation of the items which depends on the conceptualisation of cognitive load, or a too insensitive measurement.

This leads to the question of how the reported results can be interpreted in terms of the conceptualisation of cognitive load and particularly the question of how many types of load should be differentiated. The third study detected an impact of background music only on germane cognitive load, but not on intrinsic cognitive load. This supports the view of two independent types of load, which need to be measured differentiated. An independent measure of germane cognitive load was especially important in the reported studies, because we aimed to activate learners and wanted to measure explicitly this effect (see Klepsch et al., 2017).

Regarding learner´s characteristics, the importance of the trait variable working memory capacity was demonstrated in two studies: Learning with disfluent fonts as well as with background music differed for learners with different working memory capacity expressions. Also prior knowledge was confirmed to be an important variable. It needed to be controlled or, in accordance with Seufert´s (2003) assumption, restricted to a medium level in order to reach learners who are in need of an instructional aid and simultaneously are able to use it. Moreover, also the learner´s extraversion level was a crucial variable to consider while learning with background music, because results differed for learners with different extraversion expressions. However, in contrast to the two cognitive variables working memory capacity and prior knowledge and the personality trait extraversion, no significant results were found for the affective variable mood or the physiological variable arousal in the two studies including background music. It needs to be pointed out that the presence of background music failed to have an impact on mood and arousal and thus, their mediating effect on learning outcomes could not be analysed. Comparing the successfully implemented variables with the not successfully implemented variables, it becomes clear that all three trait variables (working memory capacity, prior knowledge, and extraversion) were found to moderate the learning process, while both state variables (mood and arousal) could not be tested for a mediating effect. Thus, it again needs to be pointed out how important it is to carefully design a learning environment which should have an impact on state variables. Moreover, I would recommend implementing a manipulation check for all studies investigating the influence of state variables.

So what does this mean with regard to the described processing theories from Mayer (2005) and Moreno (2006)? The results underpin Moreno´s (2006) approach that Mayer´s (2005) cognitive theory needs to be supplemented by learner´s characteristics, particularly for prior knowledge, working memory capacity, and extraversion. Unfortunately, the importance of affective or motivational learner´s characteristics were not supported by the reported results, nor did the results contradict their relevance. This is due to the already described missing variance between the experimental groups. To better investigate this question, it is essential to effectively manipulate affective and motivational variables by the instructional design. However, no specific focus was put on the question at which point of the processing these aptitudes affect learning: selection, organisation or integration (Mayer, 2005).

Besides different learner´s variables, also different levels of learning outcomes were investigated. Thus, one further point of interest is that it was shown that the use disfluent fonts had an impact on both recall and comprehension, while background music only had an influence on comprehension in study 2 and on transfer in study 3. This confirmed the assumption that they affect the learning process at different parts: While disfluency already has an impact on the processing of the text surface, background music impacts learning one step later when the text surface is transferred into meaningful sounds. This seems to affect higher levels of learning outcomes.

This all leads to the following adapted version of the integrated model which was introduced in the theory section. In contrast to the originally introduced model (see Figure 3), this adapted model only focusses on trait, but not on state variables as learner´s characteristics (see Figure 5).

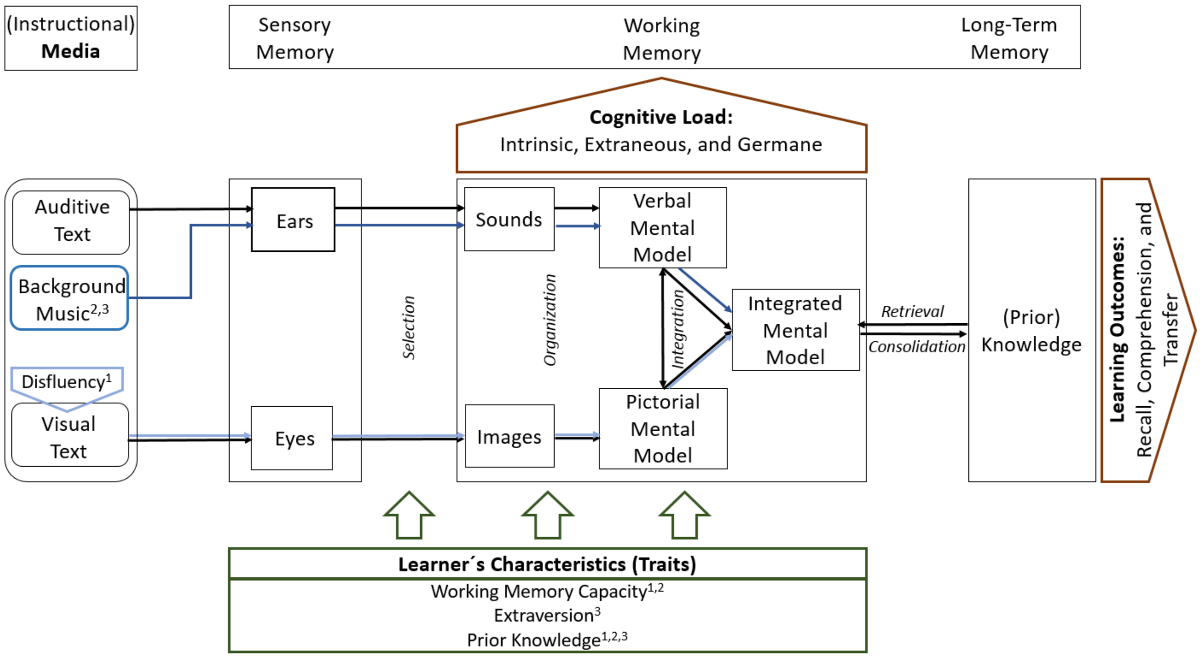

Figure 5. Adapted cognitive-affective theory of learning text under consideration of disfluency, background music, and learner´s characteristics (Numbers indicate which of the reported studies focussed on this component). Own representation based on Mayer (2005).

One further methodological issue besides the careful manipulation of state variables is the problem to detect small variances with 5- or 7-Point Likert Scales, which was mentioned repeatedly. Research in the field of learning and instruction often deals with small effect sizes, because in general, there are many different variables besides the instructional design which have an impact on learning. Thus, I would recommend a continuous measurement of variables whenever it is possible.

4.2 Practical Implications

Besides these theoretical considerations, our results also need to be reflected from a practical point of view. Regarding disfluency, the impact varies between learners with different working memory capacity. While learners with higher levels of working memory capacity seem to profit from disfluent fonts, learners with less capacity seem to learn better with easy-to-read fonts. Thus, when designing learning material for larger groups of learners with unknown learner´s characteristics it is not possible to recommend a font. Instead, it would be necessary to measure and consider the learner´s working memory capacity. Moreover, the effect of disfluency may depend on the novelty of the used fonts (Diemand-Yauman et al., 2011). There might be an adaption process in the way that the positive impact of disfluency on learners with higher working memory capacity decreases over time.

Concerning background music, results are even more complicated to interpret. The second paper (Lehmann & Seufert, 2017b) reported a negative main effect of background music on comprehension while the third paper (Lehmann et al., 2018) found a positive main effect of background music on transfer, but no impact on comprehension. Thus, results seem to highly depend on from various variables besides the pure presence of music in a learning environment such as the music´s tempo and mode, or how well the music matches specific learner´s characteristics such as the preferred genre or the habit to learn with music.

One potential problem while considering the implementation of the tested interventions is the fact that all relevant aptitudes, namely working memory capacity and extraversion, are comparably stable trait variables. Thus, they cannot be manipulated or trained by the instructional designer of a learning environment. Therefore, the only option is to measure theses aptitudes and to match the learning material to the learner and not vice versa.

However, one positive aspect of both interventions is their easiness to implement. Disfluency is a kind of surface manipulation. Thus, a text can easily and time-efficiently be adapted appropriately compared to interventions which affect deeper text structures. This allows to prepare different representations of the same learning content to consider learners with different working memory scores. Also background music can be added easily to a learning environment, because it can be implemented independently from the learning content. Moreover, in times of Spotify or Deezer the access to an almost unlimited number of different songs became available.

4.3 Limitations and Future Research

Finally, some more limitations of all three studies need to be discussed. One issue to be considered is the composition of our population. We tested high school and university students which are supposed to be over-average good learners. Moreover, all three samples included more women than men. To increase external validity, it would be interesting to repeat the reported experiments with a different population. Moreover, it needs to be pointed out that all three studies were based on experimental investigations under artificial conditions. To be able to generalize the reported effects, field studies or even better large-scale studies are necessary.

Furthermore, in all three studies, cognitive load as well as arousal and mood were measured self-reportedly and therefore, subjectively. Some of the unexpected, non-significant findings such as no impact of background music on extraneous cognitive load might also be explained by this. Participants might have been too insensitive to detect small variations in their mental load or might not have reported this small differences on a 7-point Likert-Scale. However, there are also ways for an objective and more sensitive measurement which might help explain some of the reported findings in future studies. Moreover, it might be interesting to grasp a closer look at the learner´s processes by implementing process measures such as think-aloud protocols.

One aptitude which has not gained enough attention so far is the learner´s motivation to learn, especially in the presence of background music. In the third study, background music fostered transfer outcomes which was explained by an increase in germane cognitive load. However, it might also be an increase in motivation, because in general, seductive details seem to raise motivation (Rey, 2012). Thus, future research should also include and measure motivational variables before and after the learning phase.

One further idea for future research is based on the fact that we compared only one experimental group with the control group in each study. However, both disfluency as well as background music can be used with varying intensity and thus, with varying impact. Concerning disfluency, for example, different fonts, which are increasingly hard-to-read, could be used (e.g. Seufert et al., 2017). As a next step, it might be interesting to investigate the interacting effect of these different fonts with the learner´s working memory capacity: It might be the case that for the hardest-to-read fonts working memory capacity functions only as a compensator, because there might be no capacity left for a deeper processing. This is based on the assumption that such fonts induce even more extraneous cognitive load than only moderate hard-to-read fonts. As already discussed, music and also its potential to induce extraneous cognitive load depends on the music´s characteristics, such as the presence of lyrics or the complexity of the composition. With increasing extraneous cognitive load it might become increasingly hard to compensate for the music so that positive effects on transfer might disappear.

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Appendix

I. Lehmann, J., Goussios, C., & Seufert, T. (2016). Working memory capacity and disfluency effect: An aptitude-treatment-interaction study. *Metacognition and Learning, 11*, 89-105. doi:10.1007/s11409-015-9149-z
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Working memory capacity and disfluency effect: an aptitude-treatment-interaction study

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Abstract According to Cognitive Load Theory, learning material should be designed in a way to decrease unnecessary demands on working memory (WM). However, recent research has shown that additional demands on WM caused by less legible texts lead to better learning outcomes. This so-called disfluency effect can be assumed as a metacognitive regulation process during which learners assign their cognitive resources depending on the perceived difficulty of a cognitive task. Increasing the perceived difficulty associated with a cognitive task stimulates deeper processing and a more analytic and elaborative reasoning. Yet there are studies which could not replicate the disfluency effect indicating that disfluency might be beneficial only for learners with particular learner characteristics. Additional demands on working memory caused by disfluent texts are possibly just usable by learners with a high working memory capacity. Therefore the present study investigated the aptitude-treatment-interaction between working memory capacity and disfluency. Learning outcomes were measured by means of a retention, a comprehension, and a transfer test. Moreover, the three types of cognitive load (intrinsic, extraneous, and germane) were assessed. The results revealed significant aptitude-treatment-interaction effects with respect to retention and comprehension. Working memory capacity had a significant influence only in the disfluency condition: The higher the working memory capacity, the better the retention and comprehension performance in the disfluency condition. No effects were found with respect to transfer or cognitive load. Thus, the role of metacognitive regulation and its possible effects on cognitive load need further investigation.

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Introduction

In different learning contexts such as school, higher education, vocational training or apprenticeships, teachers are concerned with the question of how to design instructional material in order to lead their students to the maximum of success in learning. Thereby, teachers as well as students may be guided by the assumption that learning material which speeds up and facilitates acquisition during instruction enhances long-term learning (Bjork 1994; Sweller et al. 1998, 2011). In contrast, there is empirical evidence for a better learning performance with disfluent learning material, which makes reading harder (Diemand-Yauman et al. 2011; Eitel et al. 2014; French et al. 2013; Sungkhasettee et al. 2011). It raises the question of whether the decision for one type of learning material depends on some special learner characteristics like prior knowledge or working memory capacity.

Disfluency effect

Recent research (Diemand-Yauman et al. 2011; Eitel et al. 2014 (Experiment 1); French et al. 2013; Sungkhasettee et al. 2011) has shown that less legible texts can lead to better learning outcomes. This so-called disfluency effect manipulates the perceived effort of learning by increasing the perceptual difficulty. Disfluent learning material is therefore a "desirable difficulty", because it doesn't affect the objective effort simultaneously, but manipulates the subjective effort (Bjork 2013). These difficulties cause an additional cognitive burden, in case of disfluency by using a harder-to-read font. Therefore learners have to engage themselves more during the learning process leading to a deeper processing and better learning outcomes.

According to disfluency theory, the disfluency effect can be assumed as a metacognitive regulation process during which learners assign their cognitive resources depending on the perceived difficulty of a cognitive task (Alter et al. 2007). Based on the assumptions of Tverski and Kahneman (1974; James, 1890/ 1950), there are two distinct processing systems in the working memory: System 1, which leads to a quick and effortless, more associative and intuitive processing, and System 2, which leads to a slow and effortful, more analytic and deliberate processing. Whereas perceiving information processing as easy activates System 1, perceiving information processing as difficult activates System 2. Thus, increasing the perceived difficulty associated with a cognitive task (i.e., disfluency) stimulates deeper processing and a more analytic and elaborative thinking rather than a heuristic and intuitive reasoning (Alter et al. 2007). Taking James (1890/ 1950) and Alter et al. (2007) into consideration, the beneficial effects of disfluency on learning outcomes can be explained by the fact that the subjective, metacognitive perception of the learning process as difficult leads to an activation of System 2. This goes hand in hand with a deeper processing and better learning outcomes (Eitel et al. 2014).

Overall, the disfluency effect has been shown only for text-based instructional material (Diemand-Yauman et al. 2011; Eitel et al. 2014 (Experiment 1); French et al. 2013; Sungkhasettee et al. 2011). It could not be demonstrated for either spoken texts (Kühl et al. 2014) or pictures (Eitel et al. 2014). Even with regard to text-based learning material, there are studies which could not replicate the disfluency effect. Whereas some studies found a neutral effect of disfluency on memory performance (Eitel et al. 2014 (Experiment 2); Guenther 2012; Song and Schwarz 2008; Rhodes and Castel 2008), other studies revealed even a negative effect of disfluency (Yue et al. 2013). Eitel et al. (2014) interpreted this heterogeneous data situation in a way that disfluent instructional material does not necessarily foster learning. Therefore they questioned on the one hand stability and generalizability of the disfluency effect, and on the other hand its impact for educational practice. Overall, it seems necessary to further elaborate on theoretical as well as on empirical issues of the disfluency effect. Hence, we first want to discuss the relationship between disfluency and cognitive load and second possible constraints of the disfluency effect with respect to specific learner characteristics.

Cognitive load theory

As described, disfluency improves learning by an evoked deeper processing. This goes hand in hand with an additional cognitive load. The Cognitive Load Theory (Sweller 1994; Sweller et al. 1998, 2011) assumes three types of cognitive load (CL): intrinsic (ICL), extraneous (ECL), and germane CL (GCL).

First, ICL is caused by the inherent complexity of the learning task and therefore by the element interactivity. The more elements a learner has to keep in mind simultaneously, the higher ICL is. Hence, ICL is fixed by a given task and cannot be influenced without changing the task. This type of load also depends on the learner's prior knowledge. With more expertise a learner is able to construct meaningful chunks of information. Hence, he or she can reduce the amount of single unrelated elements in working memory and therefore will experience less ICL. Second, ECL is caused by a poorly designed instruction and therefore completely under control of the instructional designer. This kind of load is extraneous, because the learner needs cognitive resources that are not directed to the learning task itself, but to additional demands like navigating, searching etc. If this type of load is too high learning can be massively hindered. Third, GCL reflects the learner's activities which contribute to a deeper comprehension of instructional material by processing, construction, and automation of schemas. This type of load is germane to the learning process because it is, in contrast to ECL, exclusively directed to the learning task. Hence, it is desirable to increase this type of load, e.g., by activating the learner with encouraging and motivating tasks. All three types of load are additive, e.g., together they constitute the overall amount of CL a learner is experiencing during a learning task. This CL burdens the working memory whose capacity is limited (Cowan 2001; Hasselhorn and Gold 2009; Miller 1994), To prevent an overload which would inhibit learning a lot, it would be most efficient to reduce ECL and to enhance GCL to foster learning (Sweller et al. 1998, 2011).

So the disfluency effect and its additional load is contradictory to the Cognitive Load Theory (Eitel et al. 2014). Making the learning material less legible should not influence ICL or GCL, but it should affect ECL. Because of the poor instructional design, disfluent material increases ECL. On the same time, it should indeed contribute to a deeper processing of the material, because learners do have to engage themselves more. But according to Eitel et al. (2014) this does not affect GCL, because learners do not have to create any new information actively at all. According to Cognitive Load Theory, presenting disfluent material and thereby increasing ECL without increasing GCL should lead to worse learning outcomes (Eitel et al. 2014). Based on the fact that disfluent learning material causes an additional load which burdens the working memory (WM), the working memory capacity (WMC) could be a crucial factor for the success of disfluency.

Talking about the influence of disfluency on CL only makes sense if CL can be measured. Pass et al. (1994) postulate that learners are aware of their own cognitive load and that subjective ratings are therefore useful to measure mental effort in general. In further studies different researchers extended this idea to the point that all three types of cognitive load can be measured differentially (e. g., Ayres 2006; Klepsch and Seufert 2012; Paas et al. 2005).

Aptitude-treatment-interaction with working memory and prior knowledge

As already mentioned, recent research concerning disfluency showed inconsistent results. One general possibility to evaluate heterogeneous data situations is to take account of learner characteristics. It is usual that recommendations regarding multimedia design cannot be applied to all learners in the same fashion. According to the concept of aptitude-treatment-interaction (ATI; Snow 1989), instructional strategies (treatments) have different degrees of effectiveness for specific learners depending upon their individual learner characteristics (aptitudes). One important ability might be the learner's WMC. This capacity is described by the number of information which could be processed simultaneously. For deeper processing the learner needs to structure the given information and integrate information from long term memory as well as to build meaningful chunks. These chunks relieve the WM which allows to activate System 2 (Tverski and Kahneman 1974; James, 1890/ 1950) and process the information more deeply.

Additional demands on working memory caused by disfluent texts are possibly just usable by learners with a high WMC. Only learners with a high WMC might have enough capacity for the higher ECL caused by less legible texts and could engage in deeper processing and a more analytic and elaborative thinking rather than a heuristic and intuitive reasoning. WMC may work as an enhancer: *The instructional strategy of using disfluent text is only effective with sufficient WMC*. By contrast, learners with a low WMC should not be able to handle a higher ECL caused by disfluent material. Instead, the increased ECL will exceed the resources available and learners cannot allocate germane resources to the learning process. Thus, the construction of a situational model is hindered. Overall, disfluency should not be beneficial for those learners. In the case of learning with fluent material, ECL should not be increased which would result in learners with high as well as low WMC having similar learning outcomes.

Another factor which burdens the WM is the level of learning performance. Based on Blooms taxonomy for cognitive learning processes (1956) we differentiate learning outcomes that either requires learner's ability to recall, to comprehend or to apply the issue to be learned. These levels of processing also can be found in theories of text processing (e.g., Model of Text Comprehension; Van Dijk and Kintsch 1983) or in multimedia learning theories (e.g., Mayer 2005; Schnotz 2005). These approaches explain how texts are processed. First the learner constructs a mental representation of the text surface (through subsemantic processing). Second, he or she generates a propositional representation of the semantic content (through semantic processing). Third, the learner constructs a mental model of the subject matter the text deals with. Overall, these construction processes result from bottom-up as well as top-down activation of cognitive schemata.

While easier tasks like recall tasks only burden the WM little, more difficult tasks like comprehension or transfer tasks need more WMC. For higher order cognitive processes learners have not only to keep in mind single unrelated elements, but to combine them or even integrate information from long term memory, like we just described the processes activated by system 2. So WMC is the crucial factor if learners with a disfluent learning material can also handle more difficult tasks. There is also empirical evidence for different consequences of disfluent material. Whereas Diemand-Yauman et al. (2011), French et al. (2013), and Sungkhasettee et al. (2011) showed beneficial effects of disfluency on retention, Eitel et al. (2014) demonstrated improvements in transfer. Thus, disfluency might increase learning outcomes on the lower as well as higher order levels of processing if the WMC is sufficiently high.

One more, in many studies learners' prior knowledge has been addressed as one crucial learner characteristic that moderates the effects of instructional design strategies (Kalyuga 2007; Seufert and Brünken 2004). While novice learners often benefit from an extended instructional design like providing additional pictures to a text, expert learners do not need such a support or may even suffer when additional information has to be actively disregarded and need some extra effort (expertise reversal effect; Kalyuga et al. 2003; Seufert 2003). Learners' prior knowledge works as a compensator for instructional shortcomings (Mayer and Sims 1994). Hence, ATI suggests that optimal learning results when the instruction fits exactly the learner's aptitudes.

Thus, disfluency might be beneficial only for learners with particular learner characteristics. Learners with too little prior knowledge are not able to build chunks. To process all single information burdens the WM and in addition with disfluent learning material leads to a cognitive overload. On the other side experts don't need furthermore help. They would only suffer when they have to invest additional cognitive resources related to disfluency (based on Seufert 2003). This is why we included only learners with a medium level of prior knowledge in our further analyses.

Potential confounding variables

According to the INVO-Model (*In*dividuelle *Vo*raussetzungen erfolgreichen Lernens; individual determinants of successful learning; Hasselhorn and Gold 2009), there are several determinants which play a crucial role in successful learning generally. Since the enjoyment during task performance, the interest in a task, the motivation to solve a task, and the prior knowledge have an influence on learning outcomes, these variables were assessed as potential confounding variables in the present study. Especially the motivational and affective variables could be relevant for learners' reaction on disfluent texts. Learners may decide to invest more or less mental resources based on their motivational or affective states and whether they find it motivating or frustrating to learn with such material. Nevertheless, we just controlled for these variables and did not include them as independent factors but focused on the interaction with WMC.

Research questions and hypotheses

As set out above, disfluency can lead to a better learning performance by encouraging deeper processing. This goes hand in hand with an additional extraneous cognitive load, which may only be compensated by learners with high WMC. Therefore WMC should be a crucial factor deciding if disfluency improves or inhibits learning. This leads to the question whether different results of disfluency research can be explained by an aptitude-treatment interaction between WMC and disfluency. One more it is yet unclear which levels of learning performance (retention, comprehension, or transfer; Bloom 1956) are fostered by disfluency.

So to test the enhancing effect of WMC to the different levels of learning performance, the present study investigated the ATI between WMC and disfluency. We expected an interaction between WMC and disfluency with respect to retention (*Hypothesis 1*), comprehension (*Hypothesis 2*), and transfer (*Hypothesis 3*) with stronger effects on higher levels of processing where WMC is increasingly relevant and thus can foster the construction of a situational model which is fundamental for higher test performance after learning. In the fluency condition, the WMC should not influence retention (*Hypothesis 1a*), comprehension (*Hypothesis 2a*), or transfer (*Hypothesis 3a*). In the disfluency condition, the WMC should affect learning outcomes: The higher the WMC, the better the expected retention (*Hypothesis 1b*), comprehension (*Hypothesis 2b*), and transfer performance (*Hypothesis 3b*) in the disfluency condition.

Aside from the ATI regarding learning outcomes, the present study wants to examine the theoretically expected effects of disfluency on the three types of CL empirically. According to Eitel et al. (2014), presenting disfluent material should not influence ICL or GCL, but lead to an increase of ECL. We assumed an interaction between WMC and disfluency with respect to ECL. In the disfluency condition, the expected higher ECL caused by the less legible material might be compensated by learners with a high WMC. Due to their high WMC, the increased ECL might load less on their WM compared to learners with a low WMC. In the case of learning with a fluent material, ECL should not be increased and hence learners with high as well as low WMC would experience a similar ECL.

Besides the ECL, to our knowledge, previous studies of disfluency effect have not yet used a differentiated measurement of ICL or GCL. Thus, the present study investigated the influence of disfluency on ICL and GCL. Since presenting disfluent material should not increase ICL or GCL (Eitel et al. 2014), learners with high as well as low WMC should experience a similar ICL or GCL. No main effects or interaction effects with respect to ICL or GCL are expected.

To test the effects on CL, the present study used a differentiated measurement of the three types of CL. We expected no effects regarding ICL or GCL. The fluency and disfluency condition should not differ with respect to ICL (*Hypothesis 4a*) or GCL (*Hypothesis 5a*) and there should be no interaction between WMC and disfluency regarding ICL (*Hypothesis 4b*) or GCL (*Hypothesis 5b*). Regarding ECL, we expected an interaction between WMC and disfluency (*Hypothesis 6*). In the fluency condition, the WMC should not influence ECL (*Hypothesis 6a*). In the disfluency condition, the WMC should affect ECL: The higher the WMC, the lower the expected ECL (*Hypothesis 6b*) in the disfluency condition.

Method

Participants and design

Altogether, 65 students from a German university participated for course credit and sweets in the study. As mentioned above, we excluded learners with too low (i.e., with less than 25 % of the maximum test score (=1.5 of 6 points) in the test for prior knowledge) or too high prior knowledge (i.e., with more than 75 % of the maximum test score (=4.5 of 6 points) in the test for prior knowledge). Hence, 47 subjects had a medium level of prior knowledge (M=2.03, SD=1.80) and were included in the analyses. Their mean age was 22.9 years (SD=3.77) and 85 % of them were females. Participants were randomly assigned to the fluency (n=24) and disfluency condition (n=23) of the first independent variable "learning material" (treatment-factor). Their WMC served as the second independent variable (continuous aptitude-factor). As dependent variables, we measured learning performance in a retention test, a comprehension test, and a transfer test as well as ICL, ECL, and GCL.

Materials

The materials comprised a demographic questionnaire and the instructional materials. All materials were printed on sheets of paper. The text-based instructional material was adapted from a study by Schnotz and Bannert (1999). It dealt with "Time and date differences on earth" and consisted of two printed pages containing 1070 words. The text contained a table presenting eight cities from all over the world and their time differences compared to Greenwich. Text legibility was manipulated by presenting text either in easier-to-read font (Arial, 12 pt, black; legible text; see Fig. 1), or in harder-to-read font (Haettenschweiler, 12 pt, grayscale 35 %; less legible text; see Fig. 1). A similar manipulation was successfully applied in Diemand-Yauman et al. (2011) as well as in Eitel et al. (2014).

Measures

The paper-based self-developed test for *prior knowledge* consisted of six open questions about the content domain (e.g., "What are time zones?"). The open answers were compared with a predefined solution. Two points were given for each correct answer to the prior knowledge questions and the final score of the prior knowledge test was determined by adding up all points given for the prior knowledge questions. To maximize variance, three items were excluded from the analyses due to a solution probability of less than 10 % or more than 90 %. Responses ranged from 0 to 6 points.

The computer-based Numerical Memory Updating subtest of the WMC test (Oberauer et al. 2000) was used to assess *WMC*. In a 3 by 3 matrix, an increasing number of fields were activated. In the activated fields, numbers were presented one after another. Afterwards, arrows were presented which showed upwards or downwards. Arrows showing upwards were an indicator of adding one to the previously shown numbers, whereas arrows showing downwards were an indicator of subtracting one from the previously shown numbers. Up to three operations had to be performed with the initially given numbers. Participants had to memorize the initially presented numbers and their location to perform the arithmetic operations and memorize the transformed numbers. Finally, question marks were presented and subjects had to type in the overall result. After a feedback, the next turn started with new active fields and numbers. The computer-based program worked adaptively, so that the number of activated fields in the current turn depended on the performance in the previous turn. The number of correct overall results served as the score for the WMC, which could reach a maximum value

Arial, 12 pt, black	(Haettenschweiler, 12 pt, grayscale 35%
For the purpose of navigation of ships or planes we can consider the earth as a globe. The surface of this globe is subdivided by using the so called meridians. These areas are definded as time zones.	For the purpose of navigation of ships or planes we can consider the earth as a globe. The surface of this globe is subdivided by using the so called meridians. These areas are definded as time zones.

Fig. 1 Example of the learning material (translated)

of nine. Results ranged from 1 to 6 points. Even if this test deals with numbers, it does not measure mathematical abilities. For that the calculations are too easy. Difficulties arise from keeping all the different numbers and dealing with them.

The paper-based test for *learning outcomes* comprised tests for retention, comprehension, and transfer performance. The retention (e.g., “According to which principle, the time zones were classified?”), comprehension (e.g., “What time is it in Frankfurt, when it is 2 pm in Mexico City?”), and transfer tests (e.g., “Your flight starts on 12th of July from Tokyo. After an eight-hour-flight, you arrive in Bangkok. Which date and which time is it in Bangkok?”) each consisted of five open questions about the content domain. For answering the questions in the comprehension and transfer tests, participants used a table presenting eight cities from all over the world and their time differences compared to Greenwich. The open answers were compared with a predefined solution. Two points were given for each correct answer to the retention, comprehension, and transfer questions and the final score of the retention, comprehension, and transfer tests were determined by adding up all points given for the corresponding questions. For retention, responses ranged from 1.5 to 10 points, for comprehension, they ranged from 4 to 10 points and for transfer, they ranged from 0 to 10 points.

The paper-based Cognitive Load Questionnaire (Klepsch and Seufert 2012) was used to assess ICL, ECL, and GCL. Three items assessed ICL (e.g., “For this task many things needed to be kept in mind simultaneously.”), three items assessed ECL (e.g., “The design of this task was very inappropriate to really learn something.”), and three items assessed GCL (e.g., “While solving this task, I had the goal to completely understand the subject.”). Each item had to be rated on a seven-point Likert scale (ICL—responses after learning: *Min*=1; *Max*=7; ICL—responses after assessing learning outcomes: *Min*=2; *Ma*x=7; ECL - responses after learning and after assessing learning outcomes: *Min*=1; *Max*=6; GCL - responses after learning: *Min*=1; *Max*=7; GCL—responses after assessing learning outcomes: *Min*=2; *Ma*x=7).

Three paper-based self-developed items were used to assess the potential confounding variables *enjoyment* during task performance, *interest* in the task, and *motivation* to solve the task. Enjoyment during task performance was assessed by the item “How much did you enjoy the task performance?”. Interest in the task was assessed by the item “I was interested in the tasks”. Motivation to solve the task was assessed by the item “I was motivated to solve the task”. Each item had to be rated on a seven-point Likert scale (Enjoyment ranged from 1 to 6 points after learning as well as after assessing learning outcomes; interest and motivation ranged both from 1 to 7 points).

Procedure

The study was conducted in one session, lasting about 45 min. The participants were tested in groups. After filling in the demographic questionnaire and completing the test of prior knowledge, the learning phase began for all participants simultaneously. Subjects were then asked to deal individually with the learning material. Afterwards, participants had to fill in the Cognitive Load Questionnaire and rate the enjoyment, interest, and motivation they experienced during learning by responding to the respective items. Thereafter, students were asked to fill in the tests for learning outcomes without any time restrictions. At the end, they had to fill in the Cognitive Load Questionnaire and rate the enjoyment, interest, and motivation they experienced during the tests for learning outcomes by responding to the respective items. In a prior study, we already conducted all relevant individual determinants of our subjects such as

WMC. The corresponding data set could be linked because the same code system had been used to identify the participants.

Results

To test our hypotheses we set up regression analyses. Descriptive data for all variables per condition can be seen in Table 1.

Control variables

We analyzed if the potential confounding variables differ between the two groups and if they correlate with any dependent variable. In case of group differences or a significant correlation, we controlled them in further analyses (retention performance correlated with motivation during assessing learning outcomes (r=.32, p=.03), comprehension correlated with prior knowledge (r=.37, p=.01)).

Learning outcomes

Regression analyses were applied for retention, comprehension, and transfer as dependent variables with the following predictors (entered simultaneously): learning material (fluent,

Table 1 Descriptive data for all variables per condition

	Conditions			
	Fluency (n=24)		Disfluency (n=23)	
	M	*SD*	*M*	*SD*
Working memory capacity	3.96	1.23	4.09	.95
Prior knowledge	1.98	1.57	2.09	2.04
Retention (%)	59.79	17.35	61.52	18.12
Comprehension (%)	73.54	22.63	71.96	15.28
Transfer (%)	53.59	29.76	49.78	32.88
Intrinsic cognitive load after learning (%)	67.66	19.91	62.73	20.34
Extraneous cognitive load after learning (%)	50.20	20.20	54.45	17.34
Germane cognitive load after learning (%)	82.14	13.92	77.81	16.39
Enjoyment during learning	3.21	1.56	3.30	1.40
Interest during learning	3.83	1.76	4.09	1.70
Motivation during learning	4.75	1.29	4.70	1.58
Intrinsic load after assessing learning outcomes (%)	77.71	18.78	76.60	17.40
Extraneous load after assessing learning outcomes (%)	45.67	19.53	52.17	18.75
Germane load after assessing learning outcomes (%)	77.49	14.56	71.43	15.53
Enjoyment during assessing learning outcomes	3.36	1.79	3.30	1.64
Interest during assessing learning outcomes	3.95	1.84	3.87	1.89
Motivation during assessing learning outcomes	5.27	1.52	4.70	1.79

disfluent), WMC, interaction term learning material × WMC, and respective significant control variables. In a first step, learning material was coded with 0 for the fluency condition and 1 for the disfluency condition. In a second step, learning material was recoded (fluency = 1, disfluency = 0) and the regression model was conducted again. This method of "re-centering", which was proposed by Aiken and West (1991), enables analyzing the specific impact of WMC for the condition which is coded with 0. The WMC as well as the control variables were z-standardized. The dependent variables were transformed in percentages.

For *retention performance*, the regression model was significant ($F(4, 44)=3.56$, $p=.01$, adjusted $R^2=.19$). The learning material was no significant predictor of retention ($\beta=2.42$, $t(44)=.53$, n.s.), indicating that the two experimental groups did not differ with respect to retention. As predicted in Hypothesis 1, the interaction term was significant in the prediction of retention performance ($\beta=11.66$, $t(44)=2.46$, $p=.02$). As predicted in Hypothesis 1a, for the fluency condition the WMC was not a significant predictor for retention ($\beta=-1.01$, $t(44)=-.35$, n.s.). As predicted in Hypothesis 1b, for the disfluency condition the WMC was a significant predictor for retention ($\beta=10.66$, $t(44)=2.86$, $p=.01$): The higher the WMC, the better the retention performance with the disfluent text. The interaction pattern is depicted in Fig. 2. The control variable "motivation during assessing learning outcomes" had a significant impact on retention performance ($\beta=5.59$, $t(44)=2.38$, $p=.02$) and had been controlled therefore.

For *comprehension performance*, the regression model was significant ($F(4, 46)=3.33$, $p=.02$, adjusted $R^2=.17$). The learning material was no significant predictor for comprehension ($\beta=-2.36$, $t(46)=-.46$, n.s.), indicating that the two experimental groups did not differ with respect to comprehension. As predicted in Hypothesis 2, the interaction term was significant in the prediction of comprehension performance ($\beta=12.62$, $t(46)=2.33$, $p=.03$). As predicted in Hypothesis 2a, for the fluency condition the WMC was not a significant predictor for comprehension ($\beta=-3.90$, $t(46)=-1.20$, n.s.). As predicted in Hypothesis 2b, for the disfluency condition the WMC was a significant predictor for comprehension ($\beta=10.66$, $t(46)=2.86$, $p<.05$): The higher the WMC, the better the comprehension performance with the disfluent text. The interaction pattern is depicted in Fig. 3. The control variable "prior knowledge" had a significant impact on comprehension ($\beta=7.90$, $t(46)=3.04$, $p<.01$).

For *transfer performance*, the regression model was not significant ($F<1$, n.s., adjusted $R^2<.01$). The learning material was no significant predictor for transfer ($\beta=-4.26$, $t(45)=-.46$, n.s.), indicating that the two experimental groups did not differ with respect to transfer. In

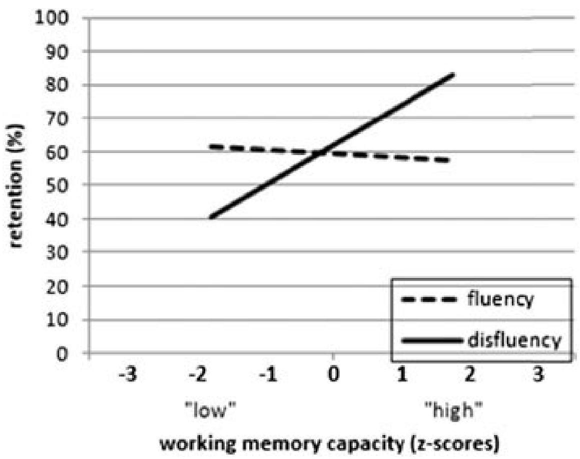

Fig. 2 Interaction between condition (fluency, disfluency) and working memory capacity for retention (controlled for "motivation during assessing learning outcomes")

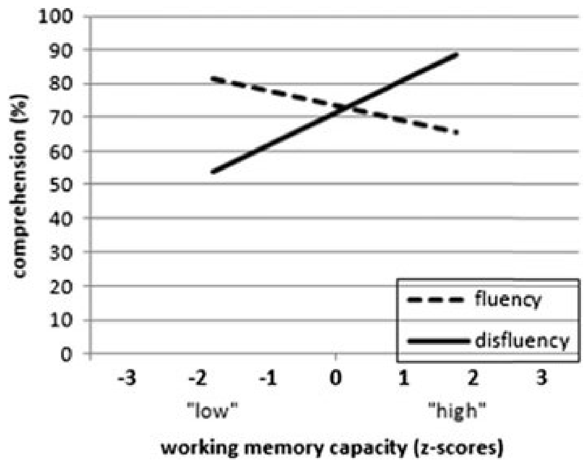

Fig. 3 Interaction between condition (fluency, disfluency) and working memory capacity for comprehension (controlled for "prior knowledge")

contrast to Hypothesis 3, the interaction term was not significant in the prediction of transfer performance (β=−2.27, t(45)=−.23, n.s.).

Cognitive load

To test the hypotheses, regression analyses were applied for ICL, ECL, and GCL (after learning and after testing for learning outcomes, respectively) as dependent variables with the following predictors (entered simultaneously): learning material (fluent, disfluent), WMC, interaction term learning material×WMC, and respective significant control variables (ICL after assessing learning outcomes correlated with enjoyment during assessing learning outcomes (r=−.36, p=.02); ECL after learning correlated with interest during learning (r=−.31, p=.04) as well as with motivation during learning (r=−.41, p<.01);), ECL after assessing learning outcomes correlated with enjoyment during assessing learning outcomes (r=−.34, p=.02), GCL after learning correlated with motivation during learning (r=.51, p<.001and GCL after assessing learning outcomes correlated with motivation during assessing learning outcomes (r=.44, p<.01)) . As in the analyses for learning outcomes, we used the "re-centering" method. The WMC as well as the control variables were z-standardized.

For *ICL* (after learning and after and assessing learning outcomes), the regression model was not significant (after learning: F<1, n.s., adjusted R^2<.01; after assessing learning outcomes: F(4, 44)=1.64, n.s., adjusted R^2=.06). As predicted in Hypothesis 4a, the learning material was no significant predictor for ICL (after learning: β=−5.44, t(46)=−.93, n.s.; after assessing learning outcomes: β=−1.55, t(44)=−.30, n.s.), indicating that the two experimental groups did not differ with respect to ICL. As predicted in Hypothesis 4b, the interaction term was not significant in the prediction of ICL (after learning: β=3.80, t(46)=.61, n.s.; after assessing learning outcomes: β=2.07, t(44)=.38, n.s.). The control variable "enjoyment during assessing learning outcomes" had a significant impact on ICL after assessing learning outcomes (β=−6.14, t(44)=−2.31, p=.03).

For *GCL* (after learning and after assessing learning outcomes), the regression model was significant (after learning: F(4, 46)=4.34, p<.01, adjusted R^2=.23; after assessing learning outcomes: F(4, 44)=2.71, p=.04, adjusted R^2=.14). As predicted in Hypothesis 5a, the learning material was no significant predictor for GCL (after learning: β=−4.92, t(46)= −1.25, n.s.; after assessing learning outcomes: β=−3.92, t(44)=−0.92, n.s.), indicating that the two experimental groups did not differ with respect to GCL. As predicted in Hypothesis 5b, the interaction term was not significant in the prediction of GCL (after learning: β=−0.79, *t*(46)=−0.19, n.s.; after assessing learning outcomes: β=2.39, *t*(44)=.54, n.s.). The control variable "motivation after learning" had a significant impact on GCL after learning (β=7.62, *t*(46)=−3.82, $p<.001$). The control variable "motivation during assessing learning outcomes" had a significant impact on GCL after assessing learning outcomes (β=6.17, *t*(44)=−2.82, $p<.01$).

For *ECL* (after learning and after assessing learning outcomes), the regression model was marginally significant (after learning: *F*(5, 46)=2.32, *p*=.06, adjusted R^2=.13; after assessing learning outcomes: *F*(4, 44)=1.93, *p*=.06, adjusted R^2=.13). The learning material was no significant predictor for ECL (after learning: β=4.31, *t*(46)=−.84, n.s.; after assessing learning outcomes: β=5.95, *t*(44)=1.08, n.s.), indicating that the two experimental groups did not differ with respect to ECL. In contrast to Hypothesis 6, the interaction term was not significant in the prediction of ECL (after learning: β=−5.11, *t*(46)=−.93, n.s.; after assessing learning outcomes: β=.51, *t*(44)=.09, n.s.). Whereas the control variable "interest during learning" had no significant impact on ECL after learning (β=−2.85, *t*(46)=−.92, n.s.), the "motivation during learning" had a significant impact (β=−6.07, *t*(46)=−2.01, $p<.05$). The control variable "enjoyment during assessing learning outcomes" had a significant impact on ECL after assessing learning outcomes (β=−5.98, *t*(44)=−2.12, *p*=.04).

Discussion

Overall, in the present study, we investigated the ATI between WMC and disfluency with respect to retention, comprehension and transfer. We found the expected enhancing effect of WMC on retention and comprehension performance: The higher the WMC, the better the retention and comprehension performance in the disfluency condition. In the fluency condition, the WMC did not influence the learning outcomes. Thus, disfluency only paid off when learners had sufficient WMC. Only with sufficient cognitive resources learners were able to use the stimulation, to intensify their learning process to a deeper level (System 2; Tversky and Kahneman 1974; James, 1890/ 1950). Without taking the WMC into account, we could not have shown the disfluency effect. Hence, a possible explanation for the heterogeneous data situation regarding the disfluency effect is that learner characteristics like the WMC have not been taken into account. Moreover, in contrast to Eitel et al. (2014) who demonstrated the disfluency effect with respect to transfer performance, we had no evidence for the disfluency effect for transfer performance in the present study—neither as a main effect nor as an ATI effect between WMC and disfluency. However, our results are partly in line with Diemand-Yauman et al. (2011), French et al. (2013), and Sungkhasettee et al. (2011) who showed the beneficial effects of disfluency on lower order processes like retention. Probably learners' WMC was again the critical factor. While disfluent material already burdens the WM, there is not that much capacity left for difficult tasks like transfer. System 2 (Tversky and Kahneman 1974; James, 1890/ 1950) could not be activated. So disfluency in addition with high cognitive load related tasks lead to a cognitive overload and therefore not to an advantage of disfluency. Finally, we could not find a general disfluency effect but only for learners with high WMC.

Further research is needed to examine these discrepancies. Additionally, it needs to be approved that one could find the same results concerning the ATI between WMC and disfluency with another measurement of WM. A subject might get a better result in the Numerical Memory Updating subtest (Oberauer et al. 2000) if he or she has an affinity towards numbers. The same property could also have influenced the results of the post test.

So maybe our measurement was confounded by this similarity. One more it should be investigated whether one could find the same results using learning material with a less mathematical topic.

Besides learning outcomes, we investigated the effects of disfluency on the three types of CL. To our knowledge, we were the first to use a differentiated measurement of the three types of CL in disfluency research. As expected, neither disfluency nor the interaction term disfluency × WMC affected ICL or GCL. Thus, our assumptions regarding ICL and GCL were supported. However, our hypotheses regarding GCL were based on the assumptions of Eitel et al. (2014). According to Eitel et al. (2014), disfluency should not affect GCL, because learners do not have to actively generate new information.

But considering the Model of Text Comprehension (Van Dijk and Kintsch 1983), one could argue that disfluency does increase GCL. According to Eitel et al. (2014), subjects learning with a disfluent text would not be forced to actively generate new information and thus there would be no increase in GCL. But GCL may not only be related to the generation of new information. Considering the text processing models, one could argue that learners receiving a disfluent text would be forced to actively invest more effort in the subsemantic processing of the text and the construction of the mental representation of the text surface. Hence, disfluency could increase GCL by intensifying subsemantic processing.

Although the present study showed that disfluency did not affect GCL, this does not necessarily have to be evidence against the assumption of disfluency increasing GCL. Eventually the Cognitive Load Questionnaire we used to assess GCL did not explicitly refer to these subsemantic processes. One more, the questionnaire only measures subjective ratings of cognitive load. Although learners are aware of their cognitive burdens, this does not mean that the ratings are conformed to the objective load coincidentally. This includes an additional metacognitive step of self-monitoring. Brünken et al. (2003) argue that objective ratings should be preferred therefore. So our results are only representative for the subjectively perceived level of cognitive load.

So, future research should investigate GCL with a questionnaire that measures GCL associated with subsemantic processing and additional objective load measures. In addition to Alter et al. (2007) who attributed the beneficial effects of disfluency to the stimulation of a deeper processing and a more analytic and elaborative reasoning, an increased GCL could explain the positive effects of disfluency, too. Another focus of prospective research is to monitor the metacognitive skill which is necessary to report your cognitive load approximately objective.

Moreover, since the majority of the studies (Diemand-Yauman et al. 2011; French et al. 2013; Sungkhasettee et al. 2011) showed the beneficial effects of disfluency only on lower order processes, this can be regarded as evidence that disfluency increases GCL by intensifying subsemantic processing. In the light of the above, the results of the present study could be explained, too. Eventually, we could not demonstrate the disfluency effect with respect to transfer, because transfer represents a higher order process.

However, we investigated the effects of disfluency on ECL. In contrast to our hypotheses, neither disfluency nor the interaction term disfluency × WMC were significant predictors for ECL. Eitel et al. (2014) could not show an increased ECL when learning with the disfluent material, too. Hence, the role of metacognitive regulation and its possible effects on ECL need further investigation. Possibly, the items which assessed ECL do not cover the different features of ECL. Disfluency might have influenced other facets of ECL, which are not included in the questionnaire we used. Moreover, the question arises, how well the subjects were able to estimate ECL. The estimation of CL depends on one's capability to introspection which was not assessed in the present study. Finally, the present study was no real exam situation, so that participants were not under pressure to perform as well as in a real exam situation. Thus, they might not consider ECL as particularly high when learning with disfluent material.

Altogether, the present study has some more limitations. First, our sample is rather small and not representative. Most of our subjects were females who were young students with—due to our numerous clauses—best results in their high school diploma and therefore probably great learning skills. Consequently, the results cannot be necessarily expected to be generalizable for other learning types. Second, we did not use any manipulation check items to evaluate the fluency or disfluency of our instructional material. The manipulation of text legibility was similar to the successful manipulation applied in Diemand-Yauman et al. (2011) as well as in Eitel et al. (2014). But there is no systematic review in which text legibility has been evaluated depending on different fonts, font colors, or font sizes. Hence, the question arises which features of the font manipulation are responsible for the disfluency effect. Since the font, the font color, and font size were manipulated in the present study, this question cannot be answered at this point and should be investigated systematically in further research. One more the role of metacognition is not clear, yet. It is thinkable that metacognitive skills like the awareness of learning with a disfluent font or monitoring cognitive load while learning impact learning outcomes. It is possible that the learner reacts rather negative by realizing that they have to invest more effort. Moreover, one crucial factor for the metacognitive decision to invest more effort due to disfluency is based on learners' sensitivity towards their own cognitive resources and their experiences with different learning materials. Only when learners realize that the material is "difficult" for them—and when they feel able to enhance their effort based on their available resources, disfluency may cause positive effects. This sensitivity towards the task properties and ones own cognitive system is the product of several learning experiences that are metacognitively monitored and evaluated. Many trainings on learning strategies address these issues and foster metacognitive awareness especially of young learners (see the meta-analysis of Donker et al. 2014).

Since the present study could show that learner characteristics like the WMC should be taken into account when investigating the disfluency effect, future research should identify other aptitudes, besides WMC, which may interact with disfluency. Especially learners' prior knowledge could be a relevant moderating variable, as has been often proved in ATI studies (Kalyuga et al. 2003; Seufert 2003). One could argue that prior knowledge also relieves learners working memory capacity due to meaningful chunks in working memory and therefore a reduced amount of intrinsic cognitive load. Hence, the effects should be the same as in the present study and disfluency should be more effective with increasing prior knowledge. Moreover, as Diemand-Yauman et al. (2011) stated, the point at which a text can be considered as disfluent but not yet as illegible should be examined. Only disfluent texts can improve learning performance—with sufficient WMC and with respect to specific learning goals—whereas illegible texts should hinder learning. But in contrast to Diemand-Yauman et al. (2011), we do not believe that teachers can integrate disfluent material so easily in their lessons. If disfluency only pays off when learners have a medium level of prior knowledge and sufficient WMC, how shall teachers identify these learners in a quick and cheap way? How can they deal with the problem that only a—possibly very small—part of their learners can profit from less legible texts? Consequently, the question on the practical application of disfluent material arises. Nevertheless we think that disfluent fonts can pay off in special learning environments, for example classes with highly talented students in the middle of a learning process of one special topic. One more one must mention that fonts are a surface characteristic which is quite easy and cheap to manipulate. In this context, future research is necessary to investigate whether the disfluency effect is only a so-called novelty effect (Tulving and Kroll 1995; Rummer et al. this issue). This would mean that the disfluency effect only occurs at the beginning when the design of the instructional material is considered new and unusual and attracts the learner's attention. Later, when learning repeatedly with the less legible texts, one might get used to this kind of texts. Possibly, the disfluent material might not seem new or unusual over time and the beneficial effects caused by disfluency might disappear. One interesting practical conclusion could be to train students' metacognitive skills by using texts with varying fonts and hence with varying fluency and by reflecting these learning experiences. Thus, learners can strengthen their metacognitive knowledge about difficulties and affordances of tasks and learn more about their way to deal with these affordances.

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The Influence of Background Music on Learning in the Light of Different Theoretical Perspectives and the Role of Working Memory Capacity

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This study investigates how background music influences learning with respect to three different theoretical approaches. Both the Mozart effect as well as the arousal-mood-hypothesis indicate that background music can potentially benefit learning outcomes. While the Mozart effect assumes a direct influence of background music on cognitive abilities, the arousal-mood-hypothesis assumes a mediation effect over arousal and mood. However, the seductive detail effect indicates that seductive details such as background music worsen learning. Moreover, as working memory capacity has a crucial influence on learning with seductive details, we also included the learner's working memory capacity as a factor in our study. We tested 81 college students using a between-subject design with half of the sample listening to two pop songs while learning a visual text and the other half learning in silence. We included working memory capacity in the design as a continuous organism variable. Arousal and mood scores before and after learning were collected as potential mediating variables. To measure learning outcomes we tested recall and comprehension. We did not find a mediation effect between background music and arousal or mood on learning outcomes. In addition, for recall performance there were no main effects of background music or working memory capacity, nor an interaction effect of these factors. However, when considering comprehension we did find an interaction between background music and working memory capacity: the higher the learners' working memory capacity, the better they learned with background music. This is in line with the seductive detail assumption.

Keywords: learning with background music, arousal-mood-hypothesis, Mozart effect, seductive detail effect, working memory capacity, aptitude-treatment interaction

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INTRODUCTION AND THEORETICAL BACKGROUND

Music has become much more readily available to the public in the past decades. One influencing factor was the increasing availability of music: whilst in the past one was in need of CDs or tapes and an according player, nowadays music can be played digitally on many different devices such as computers, mobile phones or iPods. Furthermore, the choice of available songs is almost endless due to music portals. This makes it possible to select suitable songs for different situations, such as relaxing songs for a cozy evening or activating songs before going out. Due to these advances in music technology, learning with background music has received more and more attention over the last decade (e.g., Schwartz et al., 2017).

For some situations it seems intuitive to think that music would help to enhance our experience – but how do music and learning fit together? At present the effects of background music while learning and the mechanisms behind this are unclear. On the one side, music seems to have a positive (Mozart effect; Rauscher et al., 1993) and stimulating effect (arousal-mood-hypothesis; Husain et al., 2002), which could improve learning. On the other side, background music could lead to an additional burden on working memory (seductive detail effect; e.g., Rey, 2012), thus hindering learning. To be able to simultaneously deal with the learning material and the background music, the learner's working memory capacity is a crucial factor to consider.

Background Music

In this study we define background music as music that plays in the background while studying, i.e., when reading a text. Learners are intended to listen to this music but there is no relation between the music itself and the main task, namely learning the text.

Results of studies investigating the relationship between background music and learning outcomes are varied. While some studies found no effect of background music (e.g., Moreno and Mayer, 2000; Jäncke and Sandmann, 2010) others found that it negatively impacted learning outcomes [e.g., Furnham and Bradley, 1997; Randsell and Gilroy, 2001; Hallam et al., 2002 (study 2)]. Further studies report that it has a positive impact [e.g., Hallam et al., 2002 (study 1); de Groot, 2006], especially on students with learning disabilities (Savan, 1999) or poor spelling skills (Scheree et al., 2000).

Thompson et al. (2011) gave a first hint as to why previous results were so mixed. They revealed that music characteristics like tempo and intensity have an influence on learning outcomes: only soft fast music had a positive influence, whilst loud fast as well as soft slow or loud slow music hindered learning. In addition, instrumental music disturbs learners less than music with lyrics (Perham and Currie, 2014). As each study used their own music and did not control for the characteristics of their music choice, this is one possible explanation for the heterogeneous study results mentioned above. Moreover, it seems plausible that learner's characteristics such as their musical expertise (Wallace, 1994) or their familiarity with the presented music could also impact their learning.

Importantly, it is not the characteristics of a song *per se*, but their effects on the learner which influence learning outcomes. These effects on the learner have been explained by different theoretical approaches. These can be grouped into approaches positing either a potentially positive or negative influence on learning outcomes.

The first theoretical perspective explains why background music could positively influence learning and cognitive abilities. Probably the most well-known approach in this field is the so-called Mozart effect (Rauscher et al., 1993). In this study, before completing a task that measured spatial abilities, some participants listened to a Mozart sonata, while others did not listen to any music. Participants in the Mozart condition outperformed the other group. The authors found a direct, positive influence of listening to Mozart sonatas on spatial abilities. They explain these better test results though priming effects. Even though in the experiment the exposition to music took place in advance of the task, the results are transferrable to listening to music while learning. Priming effects should be even stronger during the exposition to the stimulus and decay over time (e.g., Foss, 1982).

This priming explanation, however, was criticized by Husain et al. (2002). They formulated the arousal-mood-hypothesis. It states, that listening to background music does not have a direct influence on cognitive abilities, but affects it through the mediators of arousal and mood. The prerequisite for this assumed mediation is that background music has an impact on arousal and mood, which in turn impact learning outcomes. Moreover, the authors go one step further and postulate that this mediation effect should not only influence spatial abilities, but also cognitive performance.

When considering arousal, Husain et al. (2002) follow Sloboda and Juslin's (2001) definition, that arousal describes physical activation. The influence of listening to background music on arousal (for an overview, see Pelletier, 2004) is well-established: Music can increase or decrease arousal, mostly influenced by the tempo of a song (Husain et al., 2002). In addition, there is broad evidence of the impact of arousal on learning (e.g., Kleinsmith and Kaplan, 1963; Eysenck, 1976; Heuer and Reisberg, 2014). The Yerkes–Dodson law (Yerkes and Dodson, 1908) describes optimal arousal in a learning situation following an inverted U-shaped pattern. While learners with little arousal are not engaged enough to really invest in the learning process, too much arousal can cause distractive feelings like anxiety. Thus, a medium level of arousal is optimal for learning. In conclusion, a mediation effect of background music over arousal on learning seems probable, as there seems to be an influence of background music on arousal as well as an impact of arousal on learning.

When considering mood, the arousal-mood-hypothesis defines mood as referring to emotions (Sloboda and Juslin, 2001). Several studies have found background music to influence mood (e.g., Juslin and O'Neill, 2001; Sloboda and Juslin, 2001; Schmidt and Trainor, 2010). Background music leads to different emotions dependent on whether they are composed in a major or minor mode (Husain et al., 2002). Moreover, several theoretical approaches and studies state that mood influences learning (Ilsen, 1984; Pekrun, 2006; Goetz and Hall, 2013; Heuer and Reisberg, 2014; Pekrun et al., 2017). In general, positive mood is associated with better learning outcomes (Isen, 2002) while negative mood or boredom hinders learning (O'Hanlon, 1981; Pekrun, 2006). Based on this, a mediation effect of mood also seems plausible.

To conclude, Husain et al. (2002) state that besides these two mediation effects (mood and arousal mediating the influence of background music on learning) and in contrast to the Mozart effect, music does not directly influence learning. The authors underpinned this statement by referring to a study by Nantais and Schellenberg (1999). In this study participants listened to a Mozart sonata and to a short story and completed a spatial task after each. Participants were also asked if they liked the sonata or the story better. In general, participants performed better after listening to the stimulus (sonata or story) they preferred. Thus, Husain et al. (2002) reasoned that better cognitive performance when listening to background music is due to the exposure to a pleasant stimulus.

In sum, both the Mozart effect and the arousal-mood-hypothesis state that listening to background music can foster learning, while the arousal-mood-hypothesis also takes characteristics of the melody into account. A piece of music needs to be in the right tempo and mode to be able to evoke the appropriate arousal and mood in the learner. When investigating arousal and mood evocation, it is not enough to simply measure arousal and mood after learning, but measurements need to be taken before and after learning. Only in this way is it possible to calculate the change in arousal and mood during the learning phase.

Another completely contradictory theoretical perspective describes why background music can also have a negative impact on learning. When learning with background music, the learners have to divide their attention between the learning task and the music. Thus, they have to invest cognitive resources to process the background music in addition to the learning task, as auditive information always gets processed first (Salamé and Baddeley, 1989) and cannot be ignored (Mayer, 2001). Background music is not related to the task, but can attract the learner's attention and therefore can be defined as a seductive detail (Rey, 2012). Such information distracts the learner from the main task, i.e., the learning task, and therefore hinders learning. Hence, it is not surprising that a meta-analysis of the influence of background music that involved many types of music (including different tempi and modes) (Kämpfe et al., 2010) revealed an overall negative impact on learning. Music becomes an unnecessary burden on working memory, which is a crucial point when regarding the limitations of working memory capacity (Miller, 1994; Cowan, 2001).

Working Memory Capacity

The importance of working memory and its capacity in a learning situation is due to the fact that all information within a learning situation (including learning material, learning task, and context factors) needs to be processed within working memory. There is an ongoing debate about the structure of working memory. Baddeley (1986) and Cowan (1999) published probably the two most prominent working memory models. As the experimental group in this study has to deal with visual (reading a text) as well as auditive information (listening to background music) we will especially focus on how this information gets processed according to Baddeley's (1986) and Cowan's (1999) models.

Baddeley (1986) assumes working memory to be a system with a hierarchical structure: the central executive controls the two subsystems which are phonological loop and visuospatial sketchpad. He postulates that working memory is separated to long-term memory, even though long-term memory can have an influence on processes within working memory. For example, prior knowledge activated in long-term memory can facilitate the processing and integration of new information in working memory. Due to different independent subsystems, which work in parallel and all involve their own independent capacity, it is easier to process information of different modalities. A visual text is processed with the phonological loop after being recoded through subvocal processes. Background music is phonological information as well as it is presented auditory, and thus might overload the phonological loop. However, there is evidence that musical information gets processed in a slightly different way to verbal auditive information (Salamé and Baddeley, 1989).

Different authors assume an additional, subsystem to be responsible for processing background music, which is partly independent from the phonological loop (Deutsch, 1970; Rowe et al., 1974; Paivio et al., 1975; Rowe, 2013). Referring to this, there is more capacity available while processing music in addition to a visual text as two different subsystems are utilized, compared to the processing of auditive text in addition to a visual text processed in the same subsystem. As such, background music would still interfere with reading, but not as severely as, for example, when verbal auditive information is processed by the same subsystem.

Another approach to working memory was put forward by Cowan (1999) who proposed the embedded-processes model. Working memory in this model is the activated part of long-term memory, without differentiating between the processing of different modalities. Cowan argues, that the similarity of information has an influence on how much information can be processed simultaneously: the less similar the content and modality of the information is, the easier it is to process them simultaneously. Concerning instrumental background music and reading a text at the same time, this would mean that instrumental music would be less disruptive compared to music with lyrics or a classical auditive text because of the added verbal aspect. However, processing background music still relies on the same cognitive capacity, thus, hindering learning.

Independent of which model describes working memory better, they both assert that listening to background music while learning requires additional cognitive capacity that could otherwise be invested into the learning process. This is especially important, as working memory capacity is limited.

Working memory capacity can be defined as the number of separate concepts that can be dealt with at the same time in working memory (Cowan, 2012). Cowan (2001) states that 3–4 chunks of information can be stored and manipulated at the same time. A wide variety of studies show an advantage in learning situations for learners with a higher working memory capacity [e.g., Daneman and Carpenter, 1983; King and Just, 1991; Whitney et al., 1991; Rosen and Engle, 1998 (Experiment 1); Alloy and Alloy, 2010]: the more information an individual can deal with simultaneously, the more efficient the learning process. However, listening to background music reduces the available memory capacity for the learning process. How then do background music and working memory capacity interact?

Interaction between Background Music and Working Memory Capacity on Learning

Salamé and Baddeley (1989) postulate firstly, that it is impossible not to process auditive information and secondly, that auditive information is always processed first. Thus, only if working memory capacity is high enough do learners have sufficient capacity to invest in the learning task after processing the auditive information. In this case, appropriate background music could be of benefit to learners by influencing their mood and arousal level to an optimal state, thereby fostering the learning process. However, even for those learners melodies should be chosen that only pose a small burden on working memory. Comparing instrumental music with songs with lyrics, it seems plausible that when lyrics are present they would need to be additionally processed. According to Baddeley's (1986) model, these lyrics are auditive texts that burden the phonological loop, leading to a larger decrease in learning performance compared to an instrumental song. The same is true for Cowan's (1999) model, where the lyrics are too similar to the visual text and therefore lead to interferences during learning.

Therefore, when attempting to foster learning for high-capacity learners by improving mood and arousal, one should use a music without lyrics. In this case learners may be able to process the learning material as well as the song. Therefore, sufficient working memory capacity may compensate for the additional cognitive burden, so that the potential positive effect of the music may benefit the learner. This is comparable to the ability-as-compensator effect (Mayer and Sims, 1994), where a learner's ability (in this study: sufficient working memory capacity), is required to deal with a specific element of the instructional design (in this study: Background music).

When learners with low working memory capacity have to process background music there is not enough capacity left to invest in the learning task. Even if the learners were in a perfect learning condition concerning arousal and mood, they would not be able to learn as they simply would not be able to process the information in the learning material in addition to the music.

To our knowledge, there is no empirical evidence of the interaction between background music and working memory capacity on learning outcomes which could support these theoretical assumptions. As we defined background music as a seductive detail, we argue that research on other seductive details in interaction with working memory capacity might be transferrable. Sanchez and Wiley (2006) found, that learners with low working memory capacity were hindered in their learning if learning materials included seductive pictures in addition to the text. Interestingly, learners with higher working memory capacity were not affected by these pictures, however, their performance did not increased either. As the pictures used in Sanchez and Wiley's (2006) experiment were normed to not influence arousal or mood as our experiment does, this result is not contradictory to our assumptions. A study by Fenesi et al. (2016) found similar results: Learners with low working memory capacity perform worse when presented with irrelevant pictures in addition to learning material.

The cut-off between a working memory capacity that is "too small" and "high enough" depends on the characteristics of the learning material. Highly complex or poorly designed learning tasks burden working memory capacity more than content which is less complex or better designed (Sweller, 2010; Sweller et al., 2011). This indicated that background music should only be considered when the learning material itself is not too demanding. A similar effect is was found in a study by Park et al. (2011) where pictures were used as a seductive detail. The researchers varied the complexity of the main task and found that pictures hindered learning less when the main task was not very demanding, whereas the seductive details effect was revealed with highly demanding tasks.

Learning Outcomes

Besides the complexity of the learning material, the level of learning outcomes could also play an important role. So far, we have discussed learning outcomes in general. However, one can differentiate between different levels of learning outcomes, like recall or comprehension (e.g., Bloom, 1956). For exams it is typically necessary to remember and understand the learning content. Thus, the post-test of this study differentiates between both of these learning outcomes. To our knowledge no studies as yet differentiate between the influence of background music on recall and comprehension, so we can only establish assumptions on a theoretical basis and turn to results of comparable studies for comparisons. As cited above, in a study by Park et al. (2011) the seductive detail effect depended on task difficulty with easy tasks not affected by seductive details. Transferring these results to learning with background music and to different levels of learning outcomes, i.e., recall and comprehension, one would expect background music to influence comprehension outcomes but not recall. Easier recall tasks are a smaller burden in working memory so that a learner may be able to process background music simultaneously. In addition, working memory capacity does not play an important role, as the learner does not need a high capacity. This is also why also the interaction between both factors should not influence recall performance.

However, comprehension tasks are more demanding and are bigger cognitive burdens. In this case, background music should affect comprehension outcomes, as well as working memory capacity. Moreover, we should witness an interaction between both factors in the way described above.

Research Questions and Hypothesis

To sum up, the influence of background music on learning is not clear: while the Mozart effect (Rauscher et al., 1993) implies a direct, positive effect, the arousal-mood-hypothesis (Husain et al., 2002) postulates a mediation effect over arousal and mood. Furthermore, the seductive detail effect indicates that background music has a direct negative effect on learning. In addition, the level of learning outcomes could also play an important role. On this basis, we pose the following research questions: Does listening to background music influence learning directly or is this association mediated by arousal or mood? And which role does the learner's working memory capacity have and how does it interact with background music?

All three theoretical assumptions (Mozart effect, arousal-mood-hypothesis and seductive detail effect) have theoretical and empirical justifications. As we are the first to compare all three of these, we formulate the following in parts competing hypotheses: Background music does not influence recall (H1.1), but comprehension (H1.2):

H1.2a: Due to the Mozart effect, comprehension will be influenced positively and directly by background music.

H1.2b: Due to the arousal-mood-hypothesis, we hypothesis that arousal and mood will be related to music and learning outcomes. As we chose music that was intended to induce positive mood and learning enhancing arousal, we expect background music to influence mood positively, thus fostering comprehension. Secondly, we expect that background music to have a positive impact on arousal, with arousal improving comprehension.

H1.2c: On the basis of the seductive detail effect, we hypothesize that there will be a direct negative influence of background music on comprehension.

Several studies cited above found better learning outcomes for learners with higher working memory capacity. As we think that a higher working memory capacity is only necessary for more demanding tasks, we hypothesize that there will be no main effect of working memory capacity on (H2.1) recall but on (H2.2) comprehension, with better comprehension scores recorded for learners with higher working memory capacity.

There is a lack of research investigating the interaction between listening to background music and working memory capacity. Theoretically, we assume that learners with low working memory capacity will be overburdened by processing both the learning material and the background music. Nevertheless, learners with sufficiently high working memory capacity could benefit from the potential positive effect of background music which compensates for the additional cognitive burden (see Mayer, 2001). However, this should only be relevant for comprehension tasks which are highly demanding. Based on these theoretical assumptions and the results of transferrable studies, we hypothesize that there will be (H3.1) no interaction effect between background music and working memory capacity on recall. However, we hypothesis that (H3.2) this interaction effect will be present in the case of comprehension. More specifically, we hypothesise that there will be (H3.2a) better comprehension outcomes for learners with low working memory scores while not listening to background music. Learners with high working memory capacity, (H3.2b) will have better comprehension outcomes when listening to background music while learning.

MATERIALS AND METHODS

Subjects and Design

Data was collected from 86 university students aged between 16 and 50 years ($M_{\text{age}} = 21.37$, $SD_{\text{age}} = 4.19$), including 71 (82.6%) females. Due to their very poor test performance, five participants were defined as outliers (e.g., Barnett and Lewis, 1994). We compared all post-test scores to the predefined criteria of 20% of the possible post-test score. As these five participants reached less than 15% of the post-test score, we assume that they were not engaged enough in the learning process and we excluded their data. Hence, data from 81 participants ($M_{\text{age}} = 21.46$, $SD_{\text{age}} = 4.30$, 81.5% females) were included in further analysis.

Participants were randomly assigned to one experimental group (between-subject factor: Background music – present or absent). Working memory capacity was included in the design as an organism variable, also considered as an independent variable. As dependent variables, we measured recall and comprehension as indicators for learning performance. In addition, we measured mood and arousal as potential mediating variables. Moreover, we considered prior knowledge, musical experience, age and gender as potential covariates.

Materials and Measures

All materials besides the background music and the instruction to learn were in paper-pencil form. Due to our materials, there was no ethics approval needed for this study.

The *learning material* consisted of a visual text about time and date differences on earth that was 1070 words long. It was adapted from a study of Schnotz and Bannert (1999). The adapted version of the learning materials has successfully been used in another study by Lehmann et al. (2016). The text includes information about the concept of time and time zones as well as a table that shows exemplary time differences between different cities around the world. Learning time was limited to 7 min and 30 s. To accompany the text a test to measure *prior knowledge* was created. It consisted of six open-ended questions (e.g., "What are time zones?"). Answers were compared to predefined solutions. *Learning outcomes* were measured using five open-ended recall questions (e.g., "According to which principle were the time zones classified?") and five open-ended comprehension questions (e.g., "What time is it in Frankfurt, when it is 2 pm in Mexico City?"). Answers were again compared to a predefined solution.

As *background music*, we used two different common German songs: "Auf uns" by *Andreas Bourani* and "Nur ein Wort" by *Wir sind Helden*, both in the instrumental version. Both songs were chosen to induce positive mood. According to Thompson et al.'s (2011) results, we chose two songs with a fast tempo and presented them at a medium volume (30%) to not disturb the participants too much. The songs were presented through over-ear headphones. The two songs were played between the recorded instructions to start and stop reading. To not induce any motivational effects, participants in the control group also wore headphones but only heard the instructions to start and stop reading.

Working memory capacity was measured with the computer-based Numerical Memory Updating Test (Oberauer et al., 2000). Digits that are shown in a spatial matrix for seconds have to be stored and processed by simple additions and subtractions. The resultant capacity scores indicate how many of the nine matrix fields learners can process simultaneously.

Arousal was measured before and after learning with the subscale of the Self-Assessment Manikin (Bradley and Lang, 1994). This questionnaire measures arousal with a 9-point Likert-Scale ranging from 1 = "highly aroused" to 9 = "not at all aroused," which is illustrated by a pictorial representation of a stick figure with more or less arousal indicated by a bigger or smaller explosion in its belly.

To measure *mood* before and after learning, we used a short version of the Multidimensional Mood State Questionnaire (Steyer et al., 2004). The questionnaire consisted of 14 emotions grouped into 3 subscales: good-bad-mood (angry, happy, joyful, satisfied, unhappy, and well), awake-tired (awake, lively, rested, and tired), and calm-nervous (balanced, nervous, relaxed, and restless). Participants scored each emotion according to the question "Please score how you feel at the moment." The answer format was a 7-point Likert-Scale ranging from 1 = "completely true" to 7 = "not true." A positive score in a subscale denotes positive emotions (being in a good mood, awake, and calm), a negative score indicates negative emotions (being in a bad mood, tired, and nervous). To calculate the influence of the learning phase on emotions, we subtracted mood values before learning from values after learning. Thus, a positive value in our study symbolizes an increase in positive emotions (good mood, awake, and calm) whilst a negative value indicates an increase in negative emotions (bad mood, tired, and nervous).

In addition, we used a *demographic questionnaire* to assess each learner's age, gender and study subject. The questionnaire also included questions concerning the musical expertise of our participants: Did they have experience of singing in a choir and if so, for how many years? Did they have experience playing an instrument and if so, for how many years? Moreover, we asked participants to score how musical they would assess themselves to be on a 7-point Likert-scale. Furthermore, after the learning phase, we asked the participants in the condition with background music if they were familiar with the song they had listened to.

Procedure

Data collection took place in group sessions. First, participants were asked to formally agree to participate in the experiment and the involved data collection by signing the informed consent form. This informed the participants about the duration and tasks involved in the experiment, that data will be used anonymously, the possibility to ask questions during the data collection and to withdraw their participation at any time. All participants who agreed to the data collection then completed the demographic questionnaire, two pre-tests for arousal and mood as well as a test of prior knowledge. Following this, the learning phase took place: Participants were asked to put on the headphones and to start their track, consisting of either the instructions to start and stop learning or the same instructions but with the two songs played in between. After the learning phase, participants completed the arousal and mood questionnaires again. The post-test then took place. The whole data collection took approximately 45 min.

Covariates

To identify potential covariates, we checked whether prior knowledge, age and gender were equally distributed between the conditions. As we did not find any significant differences (all *ps* > 0.35), we did not include any covariates in further analyses.

Moreover, we analyzed whether musical experience (experience singing or playing an instrument) or familiarity with the songs influenced recall or comprehension. We did not find any significant differences between the groups (all *ps* > 0.35). Thus, musical experience and familiarity with the songs were not considered further.

RESULTS

Descriptive Data

Descriptive data concerning all dependent variables in all conditions can be found in **Table 1**.

Potential Mediators

To analyze whether background music influences learning outcomes indirectly mediated through mood or arousal, a first step is to analyze whether background music influences mood or arousal directly. If so, we will then analyze whether these variables influence learning outcomes significantly (for a theoretical approach concerning mediator analyses, see Baron and Kenny, 1986).

Arousal

Listening to background music did not influence the difference in arousal before and after learning, $F < 1$, ns. The prerequisites for a mediation were not reached in this case.

Mood

Background music did not influence the differences in moods before and after learning in the good-bad mood subscale or in the awake-tired subscale, $Fs < 1$, ns, nor the calm-nervous subscale, $F(1,77) = 1.04$, ns, $\eta^2 = 0.01$. Again, the prerequisites for a mediation were not reached.

Recall

Neither the presence of background music, $F(3,73) = 1.08$, ns, $\eta^2 = 0.02$, nor working memory capacity, $F < 1$, ns, or the interaction between both factors, $F(3,73) = 2.37$, ns, $\eta^2 = 0.09$, influenced recall significantly.

Comprehension

The presence or absence of background music, $F(1,73) = 2.90$, $p = 0.046$, $\eta^2 = 0.04$, influenced comprehension outcomes with no background music leading to better comprehension. Moreover, working memory capacity affected comprehension, $F(3,73) = 2.44$, $p = 0.035$, $\eta^2 = 0.09$, with learners with high capacity reaching better comprehension scores. A planned *post hoc* contrast revealed higher comprehension scores for participants with a working memory score of 5 than participants with a working memory score of 2 ($MD = 17.73$, $SE = 8.23$, $p = 0.017$, $d = 0.86$) or 3 ($MD = 14.18$, $SE = 6.25$, $p = 0.013$, $d = 0.68$). All other contrasts failed to show significant results.

The interaction between background music and working memory capacity was significant, $F(3,73) = 3.22$, $p < 0.028$, $\eta^2 = 0.12$ (see **Figure 1**). Planned *post hoc* contrast compared comprehension scores within the same working memory score and between the experimental groups. We found higher comprehension scores for participants with the lowest working memory score of 2 in the group with no music compared to

TABLE 1 | Descriptive data for all variables per condition.

	Conditions															
	Presence of background music															
	Without background music								With background music							
	Working memory capacity															
	2 (n = 5)		3 (n = 16)		4 (n = 10)		5 (n = 8)		2 (n = 6)		3 (n = 15)		4 (n = 7)		5 (n = 14)	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Prior knowledge (%)	45.00	17.28	22.92	15.67	35.00	19.95	32.29	19.64	8.33	7.45	28.33	21.32	26.19	17.63	33.93	15.49
Recall (%)	44.00	5.48	33.13	17.01	43.00	17.67	50.00	9.26	31.37	9.83	42.67	15.34	41.43	10.69	38.57	21.07
Comprehension (%)	70.00	14.14	48.75	22.47	57.00	24.97	72.50	14.88	33.33	13.66	58.67	24.16	55.71	27.60	65.00	19.12
Arousal (Difference after-before)*	−0.20	0.84	−0.81	1.60	−0.89	0.78	0.13	0.99	−0.33	1.37	−0.77	1.69	0.14	1.07	−0.69	2.02
Good-Bad-Mood (Difference after-before)*	0.60	4.67	0.50	5.40	−1.70	5.88	1.38	3.50	−1.83	4.79	−0.64	6.39	1.14	5.01	1.21	6.68
Awake-Tired (Difference after-before)*	−0.80	1.64	−0.06	3.68	−1.60	2.51	−0.44	3.84	1.33	3.14	−0.86	4.09	−0.29	2.56	0.71	4.99
Calm-Nervous (Difference after-before)*	−1.00	4.64	0.75	3.57	−1.00	3.37	−0.38	3.84	1.17	5.04	−0.69	4.33	1.43	5.65	1.00	3.37

** Positive values indicate an increase in this scale, negative values a decrease.*

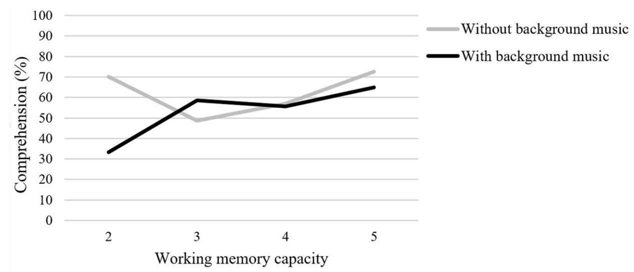

FIGURE 1 | Interaction between background music and working memory capacity on comprehension.

the group with music (MD = 36.67, SE = 13.06, p = 0.003, d = 2.64). There were no significant differences in any other contrast. Analyzing both experimental groups separately, it appears that the results of the group without background music follow a quadratic trend (MD = 18.38, SE = 7.36, p = 0.017), while the results of the group with background music follow a linear trend (MD = 20.58, SE = 7.55, p = 0.010).

DISCUSSION

The aim of this study was firstly, to examine whether background music has a direct effect on learning outcomes or whether this influence is mediated by arousal and mood. Secondly, we wanted to investigate whether the influence background music has on learning outcomes could be positive, for instance when listening to a song with specific facilitative characteristics, or whether, following the seductive detail assumption, a cognitive burden would always be present. Finally, we wanted to examine which role the learner's working memory capacity or its interaction with background music has in, speaking about learning outcomes. Results will be discussed referring to these research questions.

Mediation Effect or Direct Influence of Background Music?

To investigate whether there is a mediation effect of background music through arousal and mood on learning, we first calculated differences in arousal and mood before and after learning. As a second step, we tested whether these scores were different between the groups with or without background music during the learning phase. As there were no significant differences between the conditions, we inferred that in this study background music did not affect arousal or mood. This is contradictory to the results of previous studies (e.g., Nantais and Schellenberg, 1999; Juslin and O'Neill, 2001; Sloboda and Juslin, 2001; Husain et al., 2002; Pelletier, 2004; Schmidt and Trainor, 2010). We provide three possible explanations for these contradictory results: Firstly, the time span during which the participants were exposed to the music might have been too short to have had an impact. Learning phases in everyday life are usually much longer than in our experiment and learners may normally be exposed to music for longer periods. It might be the case, that it is necessary to listen to music for a longer time period to affect arousal or mood.

Secondly, the measurement tool might not have been sensitive enough to measure small changes in mood or arousal. The Likert scales used in this experiment consisted of seven and nine gradations of mood and arousal, respectively. Thus, in between two adjacent scale responses (e.g., between a 4 or 5) there is a 14% differences in variance in the mood scale and 11% in the arousal scale. If the influence of listening to background music was smaller than this, the measurement tool would simply not be able to account for the differences. A possible alternative approach would be to use a continuous scale. In addition, arousal could also be measured objectively with physiological data, such as heart rate, blood pressure or skin conductance.

Thirdly, contradictory to both recent explanations, it might be the case that the specific background music we used simply does not influence arousal or mood in a learning scenario such as ours. The two songs were picked based on the results of earlier studies concerning song characteristics. We chose fast paced songs to induce arousal and played them at a medium volume in line with Thompson et al.'s (2011) findings. Moreover, we used songs with a positive sounding melody which have positive lyrics in their original version. Nevertheless, it could be the case that these characteristics did not fit our sample in terms of music taste. For example, if a section of our sample did enjoy the music genre whilst the others did not the positive and negative effects may cancel each other out. This idea is supported by the rather high standard deviations in the scales, as well as the different high scores between the different levels of working memory capacity, see **Table 1**. Moreover, contradictory to Thompson et al.'s (2011) findings Hallam et al. (2002, study 2) found that fast music negatively influenced learning outcomes. This contradiction emphasizes how important it is to control for learners' characteristics in studies and, in addition, to be precise with the description of the musical stimuli, so that "fast music" is understood in replicable terms in all studies.

In summary, we were not able to confirm the arousal-mood-hypothesis, as background music did not affect arousal or mood in our study. However, besides arousal and mood, there are other learners' characteristics which could potentially be mediators not tested in this study, such as learner motivation. Anyway, did background music have a direct, positive or negative influence on learning outcomes in this study?

Concerning recall, background music did not influence performance, confirming our hypothesis. Therefore, the potential positive effect on cognitive abilities postulated by Rauscher et al. (1993) and the seductive detail effect (Rey, 2012) either do not benefit the learner or indeed cancel each other out. As recall tasks only place as small burden on working memory, there is still enough capacity left after processing background music. A study by Brünken et al. (2004) supports this idea as they did not find an influence of listening to background music on cognitive load while completing a simple recall task. Thus, background music did not influence recall negatively. We believe that there is neither a positive, nor a negative impact on recall and no compensation effect. However, if one would like to affect recall through music, some success has been found by using jingles to improve recall for short verbal sequences (e.g., Yalch, 1991; VanVoorhis, 2002).

When considering comprehension, learners reached higher levels of learning with no background music. This result lends support to our seductive detail hypothesis (1.2c): As background music is always processed first (Salamé and Baddeley, 1989) there is not enough capacity left to work on cognitively demanding comprehension tasks. In conclusion, this was the only association which we found between background music and learning outcomes, direct or indirect. This indicates that besides the arousal-mood-hypothesis, the Mozart effect hypothesis also needs to be rejected. In this study, background music functioned as a seductive detail for more demanding learning processes such as comprehension.

A further point which needs to be considered is that the songs we used were instrumental versions of popular songs with lyrics. Even though we did not present the lyrics they may have been activated by the melody as an anchor (see for example, Bartlett and Snelus, 1980; Wallace, 1994). On the one hand, the activated lyrics interfere with the text the participants have to learn in working memory, as participants would have to deal with both simultaneously. On the other hand, participants would need less effort to process the melody, as familiar information is easier to process than unfamiliar information (Hulme et al., 1991). Taken together, the negative and positive effects may cancel each other out and may explain why in our study, we did not find any influence of learners' familiarity with the songs on learning outcomes.

Working Memory Capacity

Answering our second research question, working memory capacity did not influence recall performance As in the explanation above, recall tasks do not demand much cognitive capacity and because of this, all learners should be able to process the relevant content, independent of their working memory capacity. However, comprehension tasks require more cognitive capacity. Hence, in support of our hypothesis, learners with higher working memory capacity reached higher comprehension scores as they are able to process more units of information simultaneously allowing them to better understand the test.

Interaction between Background Music and Working Memory Capacity

The last research question concerned the interaction between background music and learners' working memory capacities. In the case of the recall tasks, neither background music nor working memory capacity played a crucial role. Even learners with little capacity should be able to process background music in addition. Indeed, we found conformation of our hypothesis that the interaction between both factors did not influence recall performance.

In the case of comprehension, however, we found a significant interaction between listening to background music and working memory capacity. The only significant and relevant contrast occurred in the learners with the lowest working memory capacity who reached higher comprehension scores without background music. As their working memory capacity is highly limited, they are simply not able to process a comprehension tasks and background music simultaneously. For all of the other capacity levels we did not find such a difference or indeed, any advantages when learning with music. This finding is also in keeping with the seductive detail assumption and comparable to the ability-as-compensator effect (Mayer and Sims, 1994).

In line with this result, we found a linear trend in the group which learned with background music. The higher a learner's working memory capacity, the better they learn with background music. Whilst processing the music, they still have enough capacity left for the main learning task. We found a quadratic trend when analyzing the group without background music. As expected, learners with medium working memory capacity performed worse than those with high working memory capacity scores. Unexpectedly, learners with low working memory capacity scores outperformed the medium capacity groups and their results matched that of the high-capacity group. We expected a better performance with increasing capacity. However, Zander (2010) found that some learners may not constantly invest all of their capacities in the learning process, so that learners with beneficial learning characteristics do not necessarily outperform those learners with poor skills. In this context we also need to point out that our sample for the extreme group analysis was rather small. Therefore, effects might also have been attributed to other variables such as motivation or situational interest, which might be unequally distributed and were not controlled for.

Limitations and Further Research

As in all studies involving music, these results are not simply transferable to learning with other songs. If at all, one would expect similar results when using songs with the same characteristics, such as tempo or mode. The background music in this study did not influence arousal or mood as expected. It is therefore important that a learner's attitude concerning the presented music need to be taken into account. Further research need to investigate whether one would reach the same results while testing participants with different characteristics. Furthermore, the direct negative influence of background music needs further investigation. Even though we found evidence of a seductive detail effect, this result needs to be validated by measuring cognitive load after learning with and without background music, and differentiated for all three types of load during solving recall and comprehension tasks. For this, one could use the cognitive load questionnaire developed by Leppink et al. (2013). Furthermore, it would be interesting to assess how exactly background music impacts learning on a cognitive basis: For example, the question of how exactly background music is processed is still an open one.

Moreover, as mentioned above, we recommend using a more sensitive measuring tool than we did. Our tools were not able to detect small variations in either arousal or mood. We would suggest using continual instruments to pick up on subtle chances in variance.

In addition, working memory capacity is also discussed as being relevant in the context of creativity (e.g., Jalil, 2007; Vandervert et al., 2007; Sharma and Babu, 2017). Therefore, it might be interesting for further research to consider creativity as another aptitude variable in the context of learning with background music. For example, we could imagine that highly creative learners may especially benefit from listening to background music while learning. Moreover, it could also be relevant to measure the impact of the interaction between background music and working memory capacity on creative learning tasks.

Practical Implications

Based on the results of this study, we cannot recommend learning with background music. Learners with the lowest capacity levels were especially impaired by background music. With increasing working memory capacity background music neither hindered nor fostered learning. For these learners it is merely a matter of personal preference as to whether they wish to learn with background music or not, for example in an attempt to raise their motivation levels. However, learners should be careful with their decision as to which music they chose to listen to: Song with lyrics are potentially more distracting than instrumental melodies and music with other modes or tempos could possibly evoke obstructive emotions for learning. Luckily, there is enough music readily available, so that each of us has the chance to listen to our preferred music, which may even be conducive to learning.

ETHICS STATEMENT

Our study is about learning with or without background music. There was no potential to harm or endanger any participants. Moreover, we did not collect any sensitive data. Hence, there was no offical ethics approval needed.

AUTHOR CONTRIBUTIONS

JL designed and conducted this study and wrote this manuscript – all under supervision of TS.

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SPECIAL ISSUE ARTICLE

WILEY

The influence of background music on learners with varying extraversion: Seductive detail or beneficial effect?

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Summary

Seductive details in general affect learning and cognitive load negatively. However, especially background music as a seductive detail may also influence the learner's arousal, whose optimal level depends on the learner's extraversion. Therefore, the effects of extraversion and background music on learning outcomes, cognitive load, and arousal were investigated. We tested 167 high school students and found better transfer outcomes for the group with background music. They also reported higher germane load, but no impact of background music on extraneous cognitive load or arousal was found. In the group without background music, learners with higher extraversion reached better recall scores, which was not found in the group with background music. Results may cautiously be interpreted that there is a beneficial impact of background music that compensates for the disadvantages of low extraverted learners and which cannot be explained through arousal.

KEYWORDS

aptitude-treatment-interaction, background music, cognitive load, extraversion, seductive details

1 | INTRODUCTION

Instructional designers aim at providing learning material that is attractive to learners, thereby fostering motivational processes. However, sometimes, learners themselves also decide to enrich their learning setting to raise motivation, for example, by listening to background music while learning. Such attractive but—in terms of information processing—irrelevant aspects are called seductive details (Garner, Gillingham, & White, 1989; Mayer & Fiorella, 2014). Research indicates that seductive details generally have a negative impact on learning (Rey, 2012). However, whether music can be helpful for learning or hinders learning might be individual and dependent from learners' characteristics. One of these individual mechanisms might be that listening to background music influences the learner's arousal level (e.g., Pelletier, 2004). For example, people with different levels of extraversion prefer different levels of induced arousal: The higher the extraversion level, the greater the preferred induced arousal (Eysenck, 1967, 1994; Eysenck & Eysenck, 1985) and vice versa. This is why the learner's extraversion level might be an important variable to be considered while analyzing the effects of background music.

2 | BACKGROUND MUSIC AS A SEDUCTIVE DETAIL

As outlined above, seductive details are potentially attractive pieces of information added to the learning material, which are unnecessary for understanding the learning content (Garner et al., 1989; Mayer & Fiorella, 2014). In this paper, we refer to Mayer and Fiorella's work (Mayer & Fiorella, 2014) and his broader understanding of seductive details: We consider all unnecessary but attractive information as seductive details, which need to be processed by the learner and are part of the learning environment, but not necessarily of the learning material. Seductive details can be visual stimuli such as pictures (e.g., Harp & Mayer, 1998) or additional texts (e.g., Garner et al., 1989; Harp & Mayer, 1998; Park, Flowerday, & Brünken, 2015), as well as auditive information such as sounds or background music (Lehmann & Seufert, 2017; Grice & Hughes, 2009; Mayer & Fiorella, 2014; Moreno & Mayer, 2000). The idea behind adding seductive details is to raise the learner's interest and enjoyment, thereby fostering learning (cf. Harp & Mayer, 1998). Specifically, in regard to background music, it might motivate the learner to adopt a general state of positive attitude toward the overall learning environment, which transfers to the learning content itself, for example, by an increased willingness to invest effort.

However, in his meta-analysis, Rey (2012) summarizes four main argumentations why seductive details impede learning: First, he argues that seductive details can lead to a cognitive overload. Second, seductive details distract the learner and draw their attention away from the actual learning content. Third, the presentation of seductive details may lead to inadequate schema acquisition. Fourth, seductive details hinder the construction of a coherent mental model. These explanations can be applied when explaining the influence of background music on learning: First, background music needs to be processed in addition to the actual learning content and thus, poses additional load on learner's working memory. Second, it is plausible that learners focus on the background music rather than on the learning content, as auditive stimuli are always processed first (Salamé & Baddeley, 1989). Thus, background music might split the learner's attention. Previous studies (e.g., Mayer & Moreno, 1998) have already shown that split attention generally impedes learning. And third, background music may activate schemata, which are not important for the learning content, as, for example, schemata about the musician. These schemata then might interfere with the processing of the learning content. Problems in constructing a coherent mental model should especially affect higher levels of processing, like comprehension and transfer. Thus, it might be especially interesting to analyze the effects of background music on different levels of learning outcomes.

Previous research revealed different results concerning the impact of background music on learning. While some studies found that background music impedes learning (for a meta-analysis, which reports a negative impact, see Kämpfe, Sedlmeier, & Renkewitz, 2010), another study found no impact (Grice & Hughes, 2009). However, there is also some evidence for a beneficial effect of background music on learning (e.g., de Groot, 2006; Hallam, Price, & Katsarou, 2002 [Study 1]). Thus, to understand these different effects of background music on learning outcomes, it is worth taking a closer look at the variables that might explain these differences.

For example, it would be helpful to also analyze the effects of music on cognitive load in a differentiated way. Based on cognitive load theory (Chandler & Sweller, 1991), seductive details are inherent to an inadequate instructional design and should therefore cause extraneous load. The studies that revealed beneficial effects of background music might nevertheless indicate that learners also increased germane processes of schema acquisition when listening to music (de Groot, 2006; Hallam et al., 2002). To analyze both effects of music, it is necessary to use differentiated measures of cognitive load (e.g., Leppink, Paas, van der Vleuten, van Gog, & van Merriënboer, 2013; Klepsch, Schmitz, & Seufert, 2017). Only then, one can disentangle whether an increase in load caused by background music is due to unproductive (extraneous) processes like distraction or due to an increase in germane processes (Kalyuga, 2011).

Another important variable for explaining the different effects of music on learning outcomes might be the music's potential to induce arousal: There is broad evidence that listening to music has an impact on the listener's arousal level (for a meta-analysis about the arousal decreasing effect of music, see Pelletier, 2004; for an arousal increasing effect, see Holbrook & Anand, 1990; Rickard, 2004; Salimpoor, Benovoy, Longo, Cooperstock, & Zatorre, 2009). The tempo of the song is primarily important for the amount of induced arousal (Husain, Thompson, & Schellenberg, 2002): The higher the tempo, the higher the induced arousal. The relation between arousal and learning follows a reversed u-shaped curve (e.g., Eysenck, 1976; Heuer & Reisberg, 2014). The peak of this curve does not only depend on the task (Yerkes & Dodson, 1908) but also on the learner's extraversion level (Eysenck, 1967, 1994; Eysenck & Eysenck, 1985).

3 | EXTRAVERSION

3.1 | Extraversion and learning outcomes

In recent years, researchers became increasingly interested in extraversion as a learner's characteristic that might be able to predict learning performance (Chamorro-Premuzic & Furnham, 2008). Studies investigating the relationship between the level of extraversion and cognitive ability show varying results. For example, Ackerman and Heggestad (1997) determined that the level of extraversion correlates positively with cognitive abilities, whereas another study of Moutafi, Furnham, and Crump (2003) reported this correlation as negative. These heterogeneous results are considered to be a consequence of using different intelligence tests for measuring cognitive abilities (Moutafi, Furnham, & Paltiel, 2004). For example, the study of Rawlings and Carnie (1989) indicates that extraverts show superior outcomes on intelligence tests with time–pressure. Introverts, however, perform better in written tests such as in reading comprehension tasks in a foreign language (Robinson, Gabriel, & Katchan, 1993).

3.2 | Arousal theory of extraversion

Eysenck (1967) postulates that differences between extraverts and introverts are caused by differences in their cortical activity. In general, introverts tend to have higher cortical activity and are more aroused compared with extraverts (Eysenck, 1967, 1994; Eysenck & Eysenck, 1985). Cortical activity is influenced by external stimulations, and under too high levels of stimulation, the brain protects itself by de-arousal (Eysenck, 1994).

A basic assumption of the arousal theory is that people seek to attain an optimal level of cortical arousal (Eysenck, 1967). Eysenck (1967) states that there is an inverted u-shaped relationship between the level of external stimulation and the hedonic tone, which is determined by the level of arousal. The maximum hedonic tone is only reached at a medium level of stimulation and thereby at moderate levels of arousal (Eysenck, 1967, 1994; Eysenck & Eysenck, 1985). Thus, Eysenck (1967, 1994) and Eysenck and Eysenck (1985) describe the physiological differences between introverts and extraverts and their ensuing need for external stimulation: Introverts are naturally more aroused and more vulnerable to become over-aroused by external stimulations. Therefore, they try to avoid intense stimulation like noisy settings, exciting situations, or social stimulation. On the contrary, the arousal system of extraverts requires more stimulation to attain the optimal level of arousal and maximum hedonic tone. Therefore, they engage in arousing situations and seek out stimulating environments (Eysenck, 1967, 1994; Eysenck & Eysenck, 1985).

4 | INTERACTION BETWEEN BACKGROUND MUSIC AND THE LEVEL OF EXTRAVERSION ON LEARNING OUTCOMES

Listening to background music while learning represents an external stimulation that has an impact on cortical arousal (Rickard, 2004; Sweeney & Wyber, 2002). In general, fast music seems to lead to an increased arousal, whereas slow music was found to reduce arousal (Thompson, Schellenberg, & Letnic, 2011). Thus, on the one hand, it can be expected that fast background music has a beneficial effect on the arousal level of high extraverts and therefore, positively influences their learning outcomes. In contrast, listening to fast music while learning would over-arouse introverted individuals. Slow background music, on the other hand, should be beneficial for the cortical arousal level of introverts by decreasing it. However, such a decreased arousal level should be harmful for high extraverts.

The interaction effect of background music on learning outcomes of introverts and extraverts has been investigated for many years (Avila, Furnham, & McClelland, 2011; Cassidy & MacDonald, 2007; Chamorro-Premuzic, Swami, Terrado, & Furnham, 2009; Dobbs, Furnham, & McClelland, 2011; Furnham & Bradley, 1997; Furnham & Strbac, 2002). Most of these studies actually support the assumption, that background music in general raises the cortical arousal level: They report that extraverts showed better learning outcomes than introverts without using specifically fast, arousing background music. This does not automatically mean that extraverts always profit from background music. While there is only one study reporting a stimulating effect of music on extraverts (Furnham, Trew, & Sneade, 1999), there is broader evidence suggesting that the outcomes of extraverts can also remain unaffected (Dobbs et al., 2011; Furnham & Bradley, 1997) or even be impaired by background music (Cassidy & MacDonald, 2007). Interestingly, Cassidy and MacDonald (2007) found that extraverts were more negatively affected by music with high arousal potential than by music with low arousal potential, pointing out that also extraverts may become over aroused. Furthermore, Furnham and Strbac (2002) demonstrated that complex background music and noises have equally distracting effects on learning outcomes. Thus, the reduced or unaffected outcomes of extraverts in the presence of background music observed in many studies might be explained by an unappealing choice of music. All in all, especially the music's potential to influence arousal should be considered while setting up hypotheses about the influence of background music on learning.

5 | RESEARCH QUESTIONS AND HYPOTHESES

Based on the theoretical and empirical background, we want to investigate the effect of background music on different levels of learning outcomes. We differentiate between performance in recall, comprehension, and transfer tasks. Moreover, we are especially interested in analyzing whether the learner's level of extraversion or introversion moderates the effects of background music.

With respect to the overall effect of background music irrespective of the learner's extraversion level, the first research question (Q1) is whether listening to background music influences recall, comprehension, and transfer. Based on the seductive detail assumption (Rey, 2012) and the results of Kämpfe et al.'s (Kämpfe et al., 2010) meta-analysis, we assume that:

- The presence of background music (H1) has a negative impact on recall, and even more on comprehension and transfer.

The second research question (Q2) is whether background music has a different effect on recall, comprehension, and transfer depending on the level of extraversion of the participants. According to Eysenck's arousal theory (Eysenck, 1967), introverts are more vulnerable to become over-aroused by external stimulation, whereas extraverts require external stimulation to attain the optimal level of arousal. If background music has an impact on the learner's arousal, we would assume that:

- There is an interaction between background music and the learner's extraversion level on recall, comprehension, and transfer (H2).
  - More specifically, in the condition without background music, the extraversion level should have no impact on recall, comprehension, and transfer (H2.1).
  - In the condition with background music, extraversion should have an impact on recall, comprehension, and transfer (H2.2)

Given that background music can theoretically increase or decrease the learner's arousal level, one could assume the following competing hypotheses:

1. In case that background music increases the arousal level, we would assume that recall, comprehension, and transfer should be higher for learners with increasing extraversion levels (H2.2.1a). This effect is assumed to be mediated by an increased arousal level (H2.2.1b).
2. In case that background music decreases the arousal level, we would assume that recall, comprehension, and transfer should be higher for learners with decreasing extraversion levels (H2.2.2a). This effect is assumed to be mediated by a decreased arousal level (H2.2.2b).

Moreover, we raise the third research question (Q3) of whether background music has an impact on cognitive load. Based on the argumentation of the seductive detail assumption (Rey, 2012) and empirical findings (Park, Moreno, Seufert, & Brünken, 2011; Park et al., 2015), we assume that:

- Background music leads to an increased extraneous cognitive load (H3.1).

However, as there are also studies, which show better learning outcomes for learners who learn with background music, there seem to be germane processes taking place while learning with background music. Therefore, we assume that:

- Background music leads to an increased germane cognitive load (H3.2).

6 | METHOD AND MATERIALS

6.1 | Participants and design

Data were collected from 167 students from a German gymnasium. Participants were aged between 13 and 18 years (M_{age} = 14.38, SD_{age} = 1.00), and the sample included 143 (85.6%) females. The first factor was the presence or absence of background music. While the participants were learning a visual text, randomly half of them listened to background music (experimental group), and the other half learned in silence (control group). Extraversion was the second factor and was measured as a continuous organism variable. Moreover, we measured recall, comprehension, and transfer as dependent variables and arousal before and after learning as a potential mediator. Furthermore, age, gender, and prior knowledge were considered as a potential confounding variables.

6.2 | Materials and measures

Apart from the background music, all materials were presented in printed format.

The learning material was a visual text about two musicians (Michael Jackson und Justin Bieber) and consisted of 1,223 words presented on three pages. The text describes the life of both musicians, including information about their families, religion, and scandals. Learning time was limited to 15 min. Prior knowledge was measured with 20 self-developed open-ended questions (e.g., “How many siblings did Michael Jackson have?”). The posttest for learning outcomes included open-ended questions, seven for recall (e.g., “How many Grammys did Michael Jackson win?”), four for comprehension (e.g., “What are the differences between Michael Jackson and Justin Bieber? Name three.”), and also four for transfer (e.g., “Explain two difficulties that single parents have to deal with and discuss them with reference to one of the two biographies.”). For recall tasks, the learner had to simply recall information, which were provided in den learning material. To solve comprehension tasks, the learner had to understand the given information and had to be able to compare them, for example, by finding similarities or differences. To answer transfer tasks, the learner needed to discuss learned contents in regard to common knowledge. All answers were compared with predefined solutions. Participants could reach a maximum of 28 points.

As background music, we presented Mozart's “Piano Concerto No. 6” (KV number 238). This rather soft and slow instrumental piece of music is composed in a B major key.

Extraversion was measured with the corresponding subscale of the Big Five Inventory 10 (BFI-10; Rammstedt & John, 2007; Muck, Hell, & Gosling, 2007). This subscale consists of two items to be scored on a seven-point Likert scale that ranged from 1 (*strongly agree*) to 7 (*strongly disagree*). The BFI-10 is a time-economic questionnaire, which showed sufficient levels of validity and reliability (Rammstedt & John, 2007). In their study, the BFI-10 shows only a small decrease in its effect sizes compared with its longer version. This is acceptable when considering the saving time. The BFI-10 was validated especially for school students (Rammstedt & John, 2007).

To measure arousal before and after learning, a subscale of the self-assessment manikin (Bradley & Lang, 1994) was used. The construct was measured with one nine-point Likert scale that ranged from 1 (*highly aroused*) to 9 (*not at all aroused*). The item is additionally illustrated by a stick figure with a smaller (little arousal) or bigger (higher arousal) explosion in its belly and was already used successfully in other studies (Sloan, Marx, Epstein, & Lexington, 2007).

Cognitive load was measured differentiated with the cognitive load questionnaire (Klepsch et al., 2017). Based on our hypotheses, we used the subscale for extraneous cognitive load with three items (e.g., “The design of this task was very inconvenient for learning.”) and the subscale for germane cognitive load, also including three items (e.g., “For this task, I had to highly engage myself.”) on a seven-point Likert scale from 1 (*not at all*) to 7 (*completely*). Validity of this questionnaire has been shown by a comprehensive predictive validity test. Reliability was reported by Klepsch et al. (2017) to be between α = 0.80 and α = 0.86 for all subscales.

Moreover, demographical data were collected. Participants were asked about their gender, age, and class level.

6.3 | Procedure

Before the data collection took place, parents of all students received an information letter including all relevant information about the study, such as the involved tasks, duration of the experiment, anonymous use of all collected data, and the freedom to quit the experiment at any time. Permission was sought for all students under the age of 18, while students over the age of 18 were allowed to sign the informed consent themselves. During data collection, all participants first filled out the demographical questionnaire, followed by a prior knowledge test and the pretest for arousal. Then, the learning phase began. Participants were instructed to wear their headphones and to listen to the recorded instructions, and were then asked to start reading. Learning time was limited to 15 min. And at the end, participants completed the arousal questionnaire again as well as the test on learning outcomes and cognitive load. Students were tested with their classes in their classrooms, and the experiment took about 60 min.

7 | RESULTS

7.1 | Descriptive data

All descriptive data for all variables per condition are listed in Table 1.

7.2 | Covariates

We analyzed whether the control variables (prior knowledge, age, gender) have an influence on the dependent variables (recall, comprehension, transfer). For prior knowledge, we found significant correlations with recall (r = 0.196, p = 0.005), comprehension (r = 0.215, p = 0.003), and transfer (r = 0.233, p = 0.001). Moreover, we found that age also correlated significantly with recall (r = 0.198, p = 0.005), comprehension (r = 0.166, p = 0.016), and transfer (r = 0.280, p < 0.001). Therefore, we included prior knowledge and age in all further calculations analyzing the influence on recall, comprehension, or transfer. None of the covariates correlated with the cognitive load subscales.

TABLE 1 Descriptive data for all variables in the conditions with or without music

	Conditions			
	With background music (n = 86)		Without background music (n = 81)	
	M	*SD*	*M*	*SD*
Age	14.40	0.95	14.37	1.05
Extraversion (%)	65.58	17.33	69.63	13.16
Arousal before learning (%)	40.23	16.66	43.70	17.06
Arousal after learning (%)	35.12	18.90	38.00	17.89
Prior knowledge (%)	28.22	11.82	26.50	12.15
Recall (%)	60.47	16.13	58.44	16.00
Comprehension (%)	68.31	22.82	65.12	26.35
Transfer (%)	63.08	16.71	55.56	23.22
Extraneous cognitive load (%)	48.45	16.07	49.56	15.44
Germane cognitive load (%)	61.85	15.26	56.44	14.87

7.3 | Effects on learning outcomes

To further analyze the influence of background music and extraversion on recall, comprehension, and transfer, we set up regression analyses as proposed by Aiken and West (1991). We included the predictors condition (learning with background music, learning without background music), extraversion (z-standardized), the interaction term between condition and extraversion, and the covariates prior knowledge and age.

For recall, the regression model showed significant results, $F(5, 166) = 4.52$, $p < 0.001$, $R^2_{adj} = 0.10$ (see Figure 1). Background music was not a significant predictor for recall, $\beta = 0.079$, $t(166) = 1.06$, ns. Moreover, the interaction between background music and extraversion was no significant predictor for recall, $\beta = 0.151$, $t(166) = 1.22$, ns. However, extraversion predicted recall significantly in the group without background music, $\beta = 0.325$, $t(166) = 2.61$, $p = 0.010$, but not in the group with background music, $\beta = 0.135$, $t(166) = 1.44$, ns.

For comprehension, the regression model was significant as well, $F(5, 166) = 3.49$, $p = 0.005$, $R^2_{adj} = 0.07$ (see Figure 2). Again, we found no significant influence of background music on comprehension, $\beta = 0.072$, $t < 1$, ns. The interaction between background music and extraversion was no significant predictor for comprehension, $\beta = 0.057$, $t < 1$, ns. Extraversion was neither a significant predictor in the group without background music, $\beta = 0.208$, $t(166) = 1.65$, ns, nor in the group with background music, $\beta = 0.136$, $t(166) = 1.43$, ns.

For transfer, the regression model again showed significant results, $F(5, 166) = 6.47$, $p < 0.001$, $R^2_{adj} = 0.14$ (see Figure 3). Background music was a significant predictor for transfer, $\beta = 0.184$, $t(166) = 2.52$, $p = 0.013$, and the presence of background music led

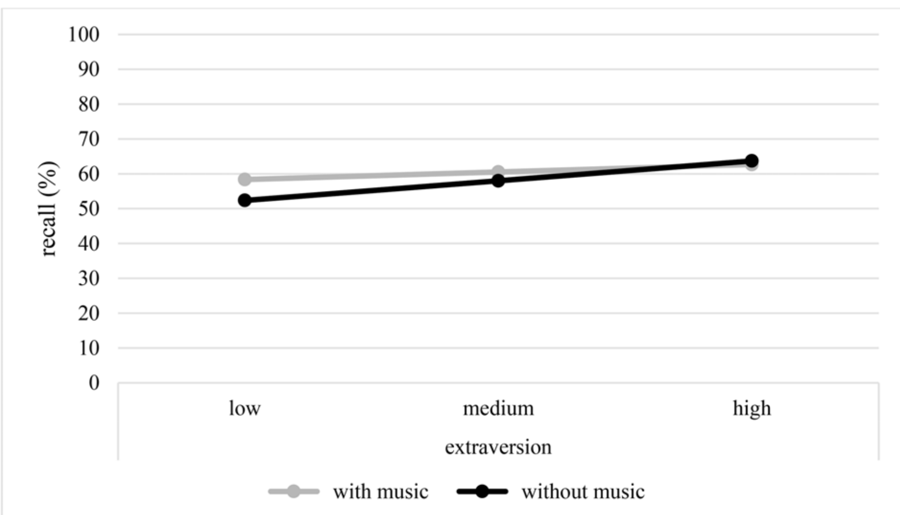

FIGURE 1 Effects of extraversion on recall for learners in the group with and without music

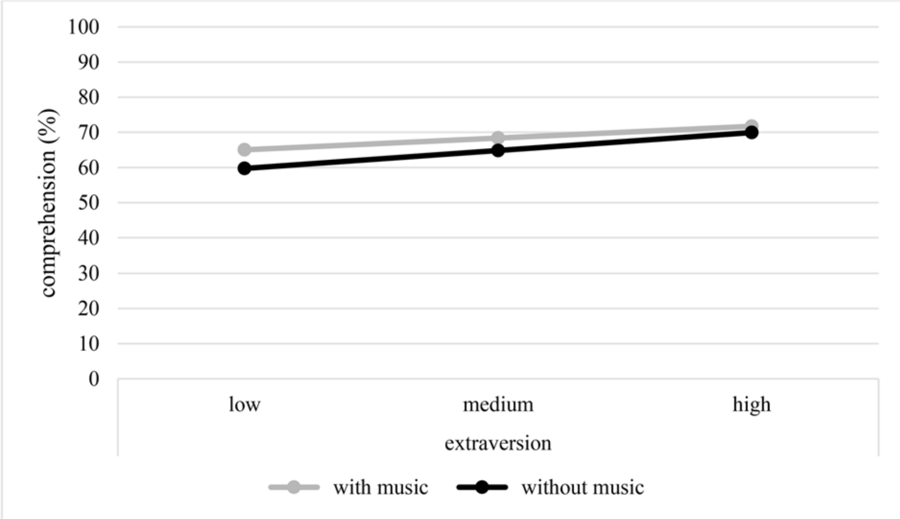

FIGURE 2 Effects of extraversion on comprehension for learners in the group with and without music

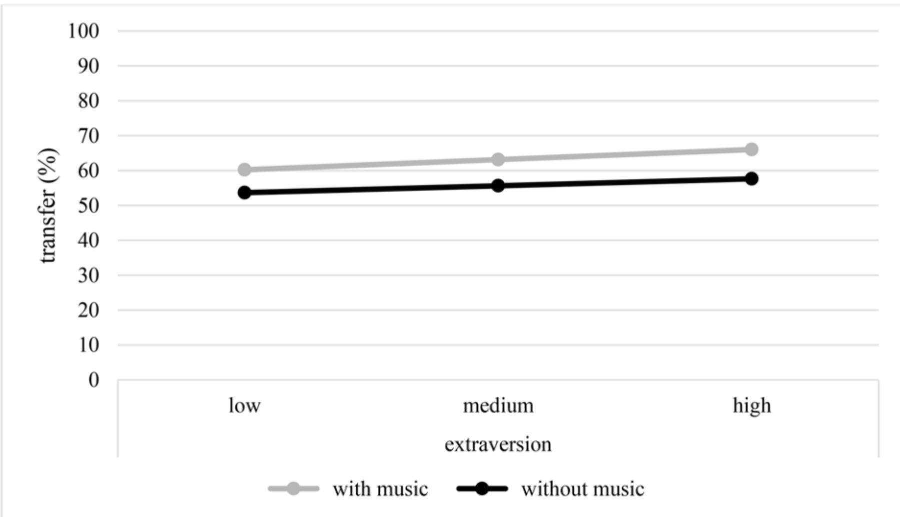

FIGURE 3 Effects of extraversion on transfer for learners in the group with and without music

to higher transfer scores. The interaction between background music and extraversion was no significant predictor for transfer, $\beta = 0.036$, $t < 1$, ns. Extraversion did not influence transfer, neither in the group without background music, $\beta = 0.097$, $t < 1$, ns, nor in the group with background music, $\beta = 0.142$, $t(166) = 1.55$, ns.

Against our expectations, background music did not influence the learner's arousal level ($F < 1$, ns). Thus, arousal cannot be considered as a mediator between background music and learning outcomes. Moreover, arousal was overall lower after the learning phase, $t(165) = 3.95$, $p < 0.001$, $d_{Cohen} = 0.31$.

7.4 | Effects on cognitive load

Extraneous cognitive load was not influenced by background music ($F < 1$, ns). However, germane cognitive load was significantly higher in the group, which learned with background music, $F(1, 165) = 5.38$, $p = 0.011$, $\eta^2 = 0.03$.

8 | DISCUSSION

In this study, we addressed the questions of whether music affects learning and cognitive load (Research Questions 1 and 3). We were especially interested in analyzing whether effects of music depend on learners' level of extraversion (Research Question 2).

Concerning the first research question, the results are not consistent for all levels of learning outcomes. Interestingly, we found no effects of music on recall and comprehension, but a beneficial effect of music for transfer. This was especially unexpected, as our learning material dealt with musicians, and the music we presented was composed from a different musician. We would have expected that this might lead to interferences and thus, especially to problems in the construction of a coherent mental model, resulting in lower transfer performance. Results did not support this assumption, as learners in the group with background music outperformed those in the group without background music in their transfer outcomes. Transfer tasks are more complex than comprehension or recall tasks and thus, require more mental effort. Therefore, a higher engagement of the learner and an appropriate schema acquisition become especially important while answering transfer questions compared with easier recall or comprehension tasks. But how can we explain the improved schema construction process?

Considering the results of the third research question regarding cognitive load might help to answer this question. One possible explanation could be the increase in germane cognitive load, which we found in the music condition. Learners, in fact, seemed to have engaged more intensively in learning when music was given. However, this engagement did not influence recall or comprehension performance. As recall tasks are comparably easy to answer, an additional engagement might not have been needed. Considering the comprehension scores, a rather high variance becomes visible. Some participants might have had problems in understanding the task, overshadowing the effect of background music.

The question of whether the increase in germane processes could be due to motivational aspects needs to be analyzed in further studies. It would also be interesting to find out which aspect of listening to background music fosters germane load and thereby learning. One possible important variable could be mood (Husain et al., 2002): There is empirical evidence, that music can influence mood (e.g., Schmidt & Trainor, 2010). In turn, positive mood seems to influence learning outcomes positively (Goetz & Hall, 2013), whereas negative mood hinders learning (O'Hanlon, 1981). Besides mood, there might also be other motivational variables, which play an important role and should be investigated in further studies.

In contrast to germane load, listening to background music had no influence on the reported extraneous cognitive load. This was against our expectations, as we thought that listening to background music poses an unnecessary burden on working memory and distracts the learner, leading to a higher extraneous cognitive load. One explanation might be that our participants were used to learning with music, so that they did not score music as an additional burden. This is in keeping with the argument of Kou, McClelland, and Furnham (2017) who discuss that there might be a habituation effect for background music for people who are used to noisy environments. Another important point would be that we used instrumental music, which is less disturbing for the learner than music with lyrics (Iwanaga & Ito, 2002). As music did not cause extraneous load, learners had sufficient capacity left to invest in germane processes.

In conclusion, background music is one kind of seductive detail, which had a positive influence on transfer performance, probably explained through an increased germane cognitive load. This is in contrast to the results of Rey's (2012) meta-analysis, which showed an overall negative effect of seductive details on learning. Most seductive details are presented visually, such as decorative pictures, thereby burdening the visual channel in working memory (Mayer, 2014). Background music, however, is presented auditorily, thereby relying on additional capacity provided through the auditive channel (Mayer, 2014). Thus, cognitive overload is prevented. This might be one reason why the presentation of background music in contrast to other seductive details did not raise extraneous cognitive load, thereby leading to a different impact on learning.

Regarding the second research question concerning the interaction between background music and extraversion, we only found differences in the recall scores of the two experimental groups: Extraversion predicted recall in the group without music, but not in the group with music. However, the overall interaction reached no significant level. Thus, one needs to be cautions when interpreting these results. The higher scores for more extraverted learners in the condition without music might be explained by the testing conditions: The students had to learn a text with limited time. Rawlings and Carnie (1989) showed in their experiment that extraverts perform better under time pressure than introverts. Moreover, we assume that the whole data collection might have been special and arousing for our participants. Taking part in a study is definitely not an everyday routine for high school students and might have particularly benefited students with higher levels of extraversion.

Interestingly, this effect disappears in the group with background music: In contrast to the group without background music, extraversion no longer predicted recall. Based on the argumentation above, this could be a hint for an arousal decreasing effect of background music, which however, was not found statistically. This might be an issue of a problematic measurement: To evaluate one's own arousal one needs interoceptive sensitivity. Interoception skills differ largely between learners (Herbert & Pollatos, 2012), and high extraverts tend to have less interoceptive sensitivity than introverts (Garfinkel & Critchley, 2013). One solution would have been to measure arousal physiologically, such as the heart rate or temperature (e.g., Burns et al., 2002). Moreover, not only the quantity of arousal but also the quality of arousal, that is, how pleasant the participants rate the arousal might be interesting. Due to the higher cortical activity of introverts (Eysenck, 1967, 1994), extraverts might judge the same amount of induced arousal more pleasant than introverts. One further problem is that arousal was measured with a seven-point-Likert scale, which means that 14% of variance is between two points of the scale. This might have been too insensitive to detect possible differences between the experimental groups on a statistically significant level.

Finally, we would like to point out the advantages of our sample and setting: We tested high school students in their classes, which leads to a higher generalizability than controlled laboratory studies. As most recent research about the influence of seductive details took place in more controlled settings, our study extends the knowledge of how seductive details and particularly background music influence student's learning outcomes.

8.1 | Limitations and further research

First, as stated above, the measurement of arousal needs further work. The same counts for the measurement of extraneous cognitive load, as our measurement did not detect differences in extraneous cognitive load between the groups with and without background music. Besides our theoretical explanations, this might also be an effect of a measurement, which was possibly not sensitive enough.

Second, we tested learning outcomes shortly after the learning phase, which is uncommon in normal school or university routines. In general, learners have to keep the learning content at least over days, if not, over weeks or months. How background music and extraversion affect long-term learning remains unclear and needs to be investigated further.

Third, further research should also focus on comparing the influence of different pieces of music, which induce a different level of arousal, that is, raise or decrease the arousal level. The choice of such music pieces could either be oriented toward music, which were already found to influence arousal in earlier studies, such as the music, which was originally used by Rauscher, Shaw, and Ky (1993). Otherwise, in case of a new, so far not validated piece of music, we would definitely recommend to implement a pretest, which measures whether a piece of music has the potential to induce or reduce arousal, before using it in a learning scenario. Arousal inducing music might lead to interesting results, especially for the interaction between background music and extraversion. Assessing the valence of learners' motivational or emotional state could complement such measures. The type of emotional state or mood or the quality of the learner's motivation, like learning versus performance goals, might also affect learners' sensibility for being affected by music.

Fourth and most importantly, our study shows that the selection of the characteristics of background music should be well considered. We have already pointed out that both the tempo as well as the key of a piece of music and thus, the induced arousal and mood need to be chosen carefully. This is in keeping with earlier research: For example, Cassidy and MacDonald (2007) examined the influence of music with high arousal potential and negative affect, music with low arousal potential and positive affect, everyday noise and silence on the outcomes in various recall tasks. Recall was overall best in the silent condition; however, introverts were more negatively affected by background sounds than extraverts (Cassidy & MacDonald, 2007). Another study of Carr and Rickard (2016) found that especially emotional music fosters memory performance. Thus, further research should also compare the influence of music with different characteristics on learning. However, it needs to be kept in mind that this paper considers background music from an instructional design perspective, where the mere presence of background music may raise the learner's interest in the learning environment. Thus, specific music characteristics play a smaller role compared with research, which focuses especially on music. Overall, the presence of background music was successfully used to foster germane cognitive load and transfer outcomes and should therefore be considered from an instructional design perspective.

CONFLICT OF INTEREST

The authors decline any potential conflict of interest.

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