Effects of Task Interruption and Background Speech on Word Processed Writing

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Summary: Task interruptions and background speech, both part of the everyday situation in office environments, impair cognitive performance. The current experiments explored the combined effects of background speech and task interruptions on word processed writing—arguably, a task representative of office work. Participants wrote stories, in silence or in the presence of background speech (monologues, halfalogues and dialogues), and were occasionally interrupted by a secondary task. Writing speed was comparably low during the immediate period after the interruption (Experiments 1 and 2); it took 10–15 s to regain full writing speed. Background speech had only a small effect on performance (Experiment 1), but a dialogue was more disruptive than a halfalogue (Experiment 2). Background speech did not add to the cost caused by task interruptions. However, subjective measures suggested that speech, just as interruptions, contributed to perceived workload. The findings are discussed in view of attentional capture and interference-by-process mechanisms.© 2016 The Authors. Applied Cognitive Psychology Published by John Wiley & Sons, Ltd.

INTRODUCTION

Employees are often interrupted at work. Causes of task interruptions are, for example, colleagues asking questions, telephone conversations and other unexpected tasks in pressing need of completion. Task interruptions increase feelings of annoyance and anxiety (Bailey & Konstan, 2006; Bailey, Konstan, & Carlis, 2001), and they increase task-completion time (Bailey & Konstan, 2006; Cauchard, Cane, & Weger, 2012; Hodgetts, Vachon, & Tremblay, 2014). Noise is another factor at work causing annoyance (Banbury & Berry, 2005; Sundstrom, Town, Rice, Osborn, & Brill, 1994), and it has negative consequences for, for example, motivation (Evans & Johnson, 2000), concentration, feelings of privacy (Banbury & Berry, 2005), satisfaction (Sundstrom et al., 1994) and performance (Loewen & Suedfeld, 1992; Sundstrom et al., 1994). Task interruptions and distraction from background noise can sometimes have dramatic consequences. In hospitals, for example, when medical workers take written note of the size of the medicine dose that should be received by a patient, or which of the two legs to be clinically removed, the consequences of even small mistakes in the written note can be horrifying. If the medical worker is interrupted or distracted when taking the written note, a failing memory can compromise the accuracy of what is eventually written.

One of the most disturbing noise sources is background speech (Sundstrom et al., 1994). Background speech has documented effects on language related tasks like writing (Keus van de Poll, Ljung, Odelius, & Sörqvist, 2014; Sörqvist, Nöstl, & Halin, 2012), proofreading (Halin, Marsh, Haga, Holmgren, & Sörqvist, 2014; Jones, Miles, & Page, 1990; Venetjoki, Kaarlela-Tuomaala, Keskinen, & Hongisto, 2006) and reading comprehension (Banbury & Berry, 1998; Martin, Wogalter, & Forlano, 1988). With few exceptions (Cauchard et al., 2012; Hodgetts et al., 2014), task interruptions and background speech have been studied in isolation, not in combination; even though they both potentially disrupt performance, lead to annoyance, and are both frequently present in the workplace. The purpose of the experiments reported in the current paper was to investigate the combined effects of background speech and task interruptions on cognitive performance in the context of an applied office-related task: word processed writing.

Various explanations of the effects of noise on performance have been offered. One view—called the interference-by-process view (Banbury, Macken, Tremblay & Jones, 2001)—is that interference between similar cognitive processes, those involved in the automatic analysis of the auditory signal and those involved in the deliberate processing of the task, disrupts performance. In writing, for example, different cognitive processes are involved, like idea generation, retrieval from memory and transformation of thoughts and ideas into words and sentences (Flower & Hayes, 1981). Most essentially, writing requires processing of meaning, which makes it especially vulnerable to disruption from background speech, as the involuntary and automatic analysis of the background speech signal also includes processing of meaning; meaning processes that come into conflict with the language processes in the writing task (Jones, Marsh, & Hughes, 2012; Marsh & Jones, 2010). For example, in a study by Sörqvist et al. (2012), normal background speech and spectrally rotated background speech (i.e., for which the acoustical characteristics are the same as in normal speech but for which there is no intelligibility) were presented as background conditions and compared with a silent control condition. There were no differences in writing performance between silence and the spectrally rotated speech condition, but a significant drop in performance was found with normal background speech. Hence, writing appears to be more sensitive to disruption from the semantic content of background speech than to disruption from the acoustical characteristics of the sound signal. This semantic effect was further investigated in more detail by Keus van de Poll et al. (2014). They manipulated the degree of speech intelligibility, as indexed by Speech Transmission Index (STI). STI is a measure of speech intelligibility with values ranging between 0 (no intelligibility at all) and 1 (perfect intelligibility). Performance was best in the condition in which the background speech had the lowest

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STI value (.23), but a significant drop in performance occurred when the speech intelligibility was only slightly higher (.34), underscoring the vulnerability of writing to background speech and its semanticity. These results fit well with the interference-by-process view of auditory distraction (Jones & Macken, 1993; Marsh, Hughes, & Jones, 2008, 2009; Marsh, Sörqvist, Hodgetts, Beaman, & Jones, 2015).

Keus van de Poll et al. (2014) also found that the number of pauses longer than 5 s, taken in the writing period, increased as speech intelligibility became higher. One interpretation of this finding is that the background speech captured attention, and drew attention away from the writing task to the background sound. This could explain why writing fluency was more impaired by background speech with higher intelligibility, as higher speech intelligibility was presumably more captivating than speech with low intelligibility. On this view, auditory distraction is not caused by interference between processes, but by an attentional capture mechanism (Hughes, 2014). Unexpected, deviant changes in the speech signal, or semantically meaningful (e.g., interesting) information in the background sound signal, capture attention from the target task, consequently leading to an interruption in the execution of the task, as attention is located elsewhere.

As sound interrupts the ongoing task-related activity, by capturing attention, there is a similarity between task interruptions caused by task-shifting (e.g., answering a phone call when writing a paper) and task interruptions caused by background sound. In both cases, every time a task is interrupted, attention shifts from the ongoing task to the source of interruption and after the interruption, attention has to be reallocated to resume the interrupted task. Several aspects of the cognitive system are involved in task interruptions caused by task-shifting and resumptions. Executive control, for example, is important in the resumption lag (the time between the end of the interruption and the resumption of the primary task) as the person has to remember what the primary task was about, what the person was doing prior to the interruption and how to continue (Trafton & Monk, 2008). In other words, the person has to regain situation awareness (Endsley, 1995). A range of factors can influence this resumption lag, depending on how disruptive the task interruption is. Generally, three factors contribute to the magnitude of disruption from task interruptions (Trafton & Monk, 2008). First, the duration of the interruption is important. The longer the interruption, the more disruptive it is. Second, rehearsal during the interruption lag (the period between the alert for and beginning of the secondary task) plays a role; rehearsal under this period can facilitate resumption of the primary task after the interruption. Third, the amount of rehearsal possible during the execution of the secondary task—to which one has shifted attention—is important. The more the secondary task prevents rehearsal of the primary task, the more disruptive the interruption will be.

Whether the interruption is caused by background sound or by an alternative task, the locus of attention will switch between the target task and the interrupting factor and will have to be reallocated when the analysis of the interrupting factor is completed. This similarity between the effects of background sound and shifting of the attentional locus between tasks suggests that the same attention reallocation mechanism could be responsible for the performance costs associated both with background sound and with task interruptions. This similarity makes it interesting to study the combined effects of task interruptions and background speech and their potential interactions.

The present experiments

See Figure 1 for an overview of the design in the two experiments reported in this paper. The main purpose of Experiment 1 was to test the general hypothesis that an interaction between background speech and task interruption should arise in the context of word processed writing (an online office-type of task), in particular for the immediate period after the interruption (i.e., at the point when the writing task is resumed). Task interruptions should disrupt performance during the most immediate period after the interruption has come to an end, because of the need for attention reallocation and regaining of situation awareness at this particular point in the writing process. The presence of background speech could enhance the disruptive effects of task interruptions, arguably by capturing attention away from the writing task, which makes it more difficult to regain situation awareness and to resume the writing task after the interruption (Hodgetts et al., 2014). The background speech employed in Experiment 1 consisted of a single male voice reciting a story. The purpose of Experiment 2 was to replicate the results from Experiment 1 and extend the findings by comparing the effect of a more realistic background speech comprising a dialogue between two individuals (in which two voices in a conversation were audible) with that of a halfalogue (in which only one of the two voices in the conversation was audible). In addition to writing, participants were asked to answer a questionnaire on workload to investigate whether subjective experiences and performance data were consistent. In Hodgetts et al. (2014), the self-reports suggested that the participants experienced higher workload and time pressure when background speech was present, and more time pressure in conditions with interruptions, but no interaction between task-shift interruptions and background sound was found.

EXPERIMENT 1

Methods

Participants

A total of 49 students (mean age = 25.1 years, SD = 3.63), amongst them 25 women, from the University of Gävle, Sweden, participated in the experiment. Data from four participants were lost because of technical errors, and those participants were discarded from the analyses. Hence, the final sample consisted of 45 participants. Participants received a small honorarium for their efforts.

Design

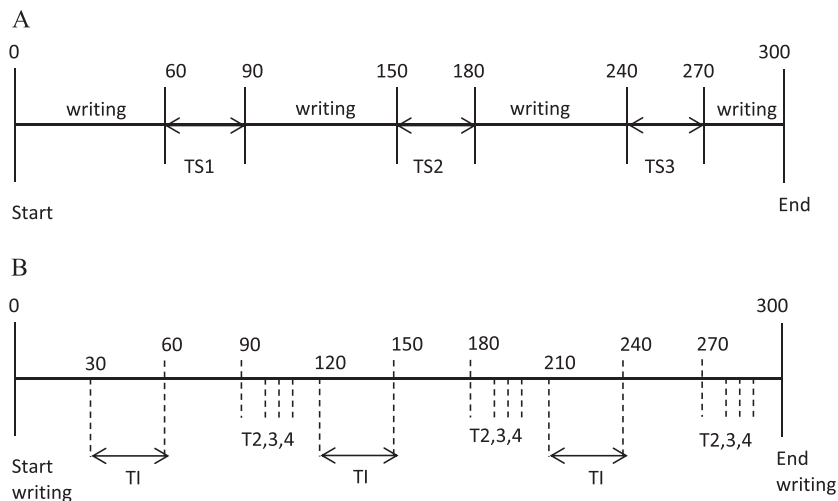A 2(Interruption: yes vs. no) × 2(Background sound condition: silence vs. background speech) × 4(Time period)

Figure 1. The figure displays the timeline for the experimental conditions, starting at 0 s and ending at 300 s. In conditions with background sound, the sound was played continuously during the whole period of 300 s. Panel A shows the position (in time) for the three task interruptions (TS1, TS2, TS3: Task Shift Interval 1, 2 and 3 respectively) as they were presented in experimental conditions with task interruptions. In experimental conditions without task interruptions, the participants continued writing during these time intervals. Panel B shows the time intervals where writing speed (characters/s) was measured (T1: the last 30 s before interruption; T2, 3, 4: the first 10 s after the interruption, the next 5 s after and the next 5 s after that, respectively). Note that the time intervals, at which point writing speed was measured, were the same for all conditions (for those with and those without interruptions, and for those with and those without background sound)

within-subjects design was used. Hence, the experiment consisted of four conditions: one silent without interruptions (writing for 5 min), one silent with interruptions (writing for 1 min, followed by a task shift for 30 s, another writing period of 1 min, a task shift for 30 s, a third writing period of 1 min, a task shift for 30 s and a final writing period of 30 s), and another two corresponding conditions with background speech instead of silence (Figure 1).

Apparatus and materials
Sound. Two different sound files were used as background speech plus one file for a practice period in the writing task. These sound files were irrelevant to the task, and consisted of stories about different topics (e.g., frogs' and fishes' ability to predict the weather). The stories were spoken by a male voice and recorded in an anechoic chamber using an artificial head (Head Acoustics HMS IV). The sounds were presented to participants through headphones (Sennheiser HD 202) at approximately 68 dBA. Sound levels in open offices are generally a bit lower (45–55 dBA) (IEC 60268-16). The time length of each sound file was 5 min. The speech signal was presented continuously, without interruptions, over the whole experimental condition, so also in the condition with both background speech and interruptions (i.e., the speech signal was played back both during the primary task—word processed writing—and during the secondary task).

Writing task. Participants were asked to write four different stories associated with four different fairy tale (or child story) characters (e.g., Pippi Longstocking; Snowwhite). The fairy tales were assumed to be familiar to all participants. A keyword presented on the computer screen told the participant which fairy tale character to write about. The key word was displayed next to a panel where the participants' written text was produced. Participants were asked to write, using the computer keyboard, as accurately and fast as possible and to avoid pauses. The instructions told the

participants to make up a new story about the fairy tale character, to tell the traditional fairy tale or to mix the traditional story with own ideas.

The time limit for every condition was set to 5 min. After 5 min, a warning signal and oral instructions, played through the headphones, told the participants to move on to the next condition by pressing a button on the computer screen. The onset and offset of the sound (in the two conditions with background speech) were synchronized with the onset and offset of the experimental condition (the sound started playing when the participants were told to start writing and stopped playing after 5 min). The writing task was introduced by a practice period of 60 s, for the participants to get acquainted with the task. In this practice period, the keyword was 'Winnie The Pooh', there was background speech, and there was also one interruption.

The software program ScriptLog was used to obtain writing responses. This program registers all keyboard activity which makes it possible to replay writing sequences for real-time analysis. Writing speed (number of characters/s) was extracted as the dependent variable, using the built in functions in ScriptLog. It was calculated for four different time intervals (see Figure 1) adjacent to each interruption (last 30 s before the interruption; 10 s after; the next 5 s after and the next 5 s after that). As there were three interruptions (in the conditions with interruptions), writing speed was collected from a total of 12 time intervals per condition. The writing speed was then averaged over the three occurrences of interruptions for each time interval respectively (one average for the time period called '30 s before the interruption', etc.). Writing speed, within these same four time intervals, was also calculated for conditions without interruptions, for comparison purposes. As no interruption took place in these control conditions, there was no break in the writing process between the time intervals called 'last 30 s before the interruption' and '10 s after'.

Interruption-task. In two of the four conditions, participants were interrupted three times per condition. Each interruption lasted for 30 s. When this happened, the participants were instructed to leave the writing task for a moment and to do a paper-and-pencil task they had at their desk. In this task, participants were asked to solve eight arithmetic problems, i.e., addition and subtraction problems (e.g., $668 + 352$; $473 - 259$). In the 60 s practice period, before the four experimental conditions, there were only four arithmetic problems of the same kind. Performance on the interruption task was not considered for analysis.

Questionnaire. After each condition respectively, the participants were requested to fill in a questionnaire, based on the NASA-TLX (Task Load Index) (Hart & Staveland, 1988). The NASA-TLX is a questionnaire developed to measure subjective workload. Five out of the six questions of the NASA-TLX were translated to Swedish and slightly re-worded to fit the current experiment (i.e., How mentally demanding was the task?; How much time pressure did you experience?; How satisfied are you with your written text?; How difficult was it for you to write the text you desired?; How insecure, stressed and/or irritated were you during the writing task?). Answers to each question were made on a 7-point Likert scale, where higher values represented more workload/dissatisfaction. Workload index scores were calculated by taking the average from the five questions. This was calculated once per condition for each participant. After the 60 s practice period, participants had only to answer the first question of the questionnaire to get acquainted with the test procedure.

Procedure

Participants sat alone in a sound attenuated room in front of a computer. They wore headphones during the whole experiment and were guided by written and oral instructions. The writing task was done on the computer, while the interruption tasks and the questionnaires were paper-and-pencil tasks. There was a practice period of 60 s before the experiment proper. At the end of each condition, the participant was asked to fill in the questionnaire and then to move on to the next condition. The order of presentation of the interruption conditions, the background speech conditions and the keywords were counterbalanced between participants following a Latin Square Design.

Results

Word processed writing

Figure 2 shows that writing speed in the first 10 s after the end of the interruption was lower in conditions with interruptions (mean = 1.25 signs/s) compared to the control conditions without interruptions (mean = 3.51 signs/s), but there were no differences between conditions for the other time intervals. In the period called 'the next 5 s after' the interruption, writing speed was back at baseline. Hence, after the interruption, it took about 10–15 s for the participants to reach the same writing speed as before the interruption. A 2(Background sound: speech/silence) × 2(Interruption: yes vs. no) × 4(Time interval: 30 s before the interruption, first
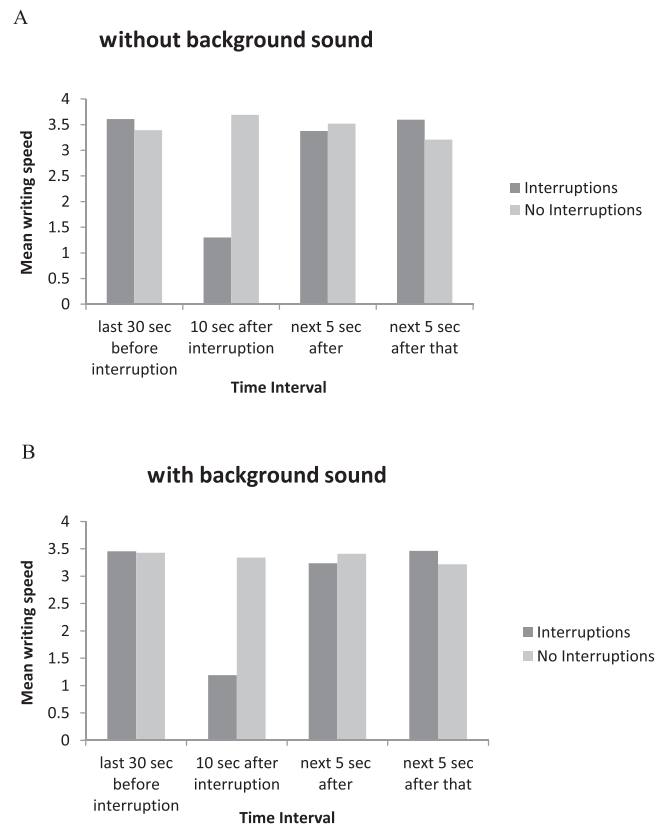

Figure 2. Mean writing speed (characters/s) for conditions with and without interruptions at four different time intervals: last 30 s before interruption; 10 s after interruption; the next 5 s after and the next 5 s after that. The data for the same time periods in the writing task are reported both in conditions without background sound (panel A) and in conditions with background sound (panel B)

10 s after the interruption, next 5 s after and the next 5 s after that) repeated measures analysis of variance (ANOVA), with writing speed as dependent variable, revealed a main effect of interruption $F(1, 44) = 81.01$, $MSE = 0.55$, $p < .001$, $\eta_p^2 = .65$, and a main effect of time interval, $F(3, 132) = 90.21$, $MSE = 0.53$, $p < .001$, $\eta_p^2 = .67$. An almost significant main effect of background sound, $F(1, 44) = 3.62$, $MSE = 0.70$, $p = .064$, $\eta_p^2 = .08$, was also found. No significant interactions were found between interruption and background sound, $F(1, 44) = 0.11$, $MSE = 0.40$, $p = .745$, $\eta_p^2 = .002$, between time interval and background sound, $F(3, 132) = 0.63$, $MSE = 0.46$, $p = .596$, $\eta_p^2 = .01$, or between time interval, background sound and interruption, $F(3, 132) = 1.16$, $MSE = 0.36$, $p = .327$, $\eta_p^2 = .03$. There was, however, a significant interaction between interruption and time interval, $F(3, 132) = 133.65$, $MSE = 0.48$, $p < .001$, $\eta_p^2 = .75$.

Re-analysis with only two time intervals. The reason why the background speech variable did not interact with the other variables was, presumably, relatively high within-person error variances in the final two time periods ('the next 5 s after' and 'the next 5 s after that'). Because of this, we ran a separate set of analyses with these two time periods excluded, to give the interactions with background speech justice. Figure 3A and 3B show that participants tend to increase writing speed when they have been working for a while, but background speech can make it difficult to reach

A

with interruptions
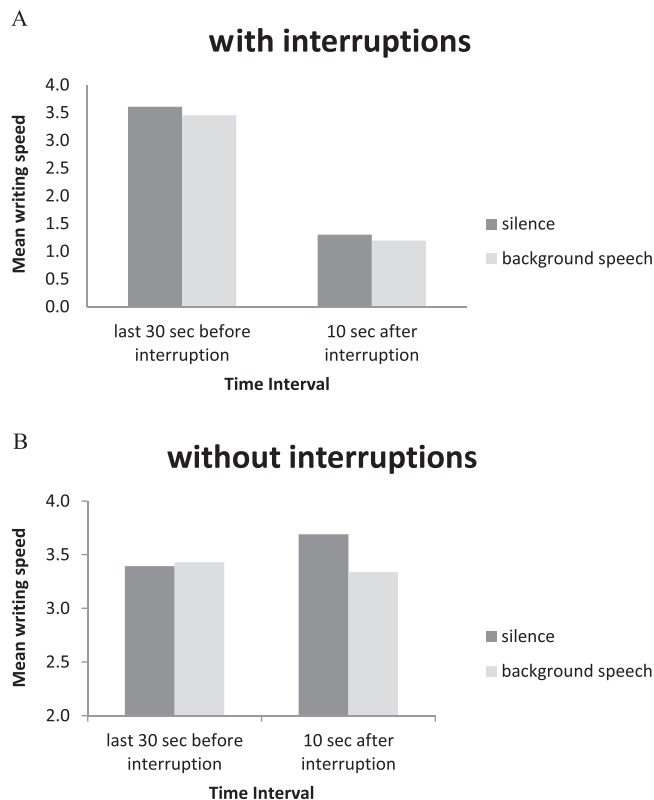

B

without interruptions

Figure 3. Mean writing speed (characters/s) for conditions with and without background sound at two different time intervals; last 30 s before interruption; 10 s after interruption and for conditions with interruptions (panel A) and without interruptions (panel B). Note that the Y-axis is truncated

these higher levels of writing speed. However, when writing speed completely comes to a stop, because of a task-switch, background speech does not add further to this writing speed inhibition. A 2(Interruptions: yes/no) × 2(Background sound: speech/silence) × 2(Time interval: last 30 s before the interruption vs. first 10 s after the interruption) ANOVA revealed significant main effects of background sound, interruptions and time interval, $F(1,44)=4.47$, $MSE=0.42$, $p=.040$, $\eta_p^2=.09$; $F(1,44)=353.37$, $MSE=0.29$, $p<.001$, $\eta_p^2=.89$, and, $F(1,44)=232.22$, $MSE=0.46$, $p<.001$, $\eta_p^2=.84$, respectively. A significant two-way interaction between interruptions and time interval, $F(1,44)=307.91$, $MSE=0.42$, $p<.001$, $\eta_p^2=.88$, and a significant three-way interaction between all factors, $F(1,44)=4.55$, $MSE=0.23$, $p=.039$, $\eta_p^2=.09$, was also found.

The interaction between time interval, interruption and background sound. To disentangle the three-way interaction, a 2(Time interval: last 30 s before interruption/10 s after interruption) × 2(Background sound: speech/silence) ANOVA was calculated for the condition with interruptions (Figure 3A) and for the condition without interruptions (Figure 3B) respectively. For the conditions with interruptions, writing speed was higher in the 'last 30 s before interruptions' compared to the '10 s after interruptions'. This main effect was significant, $F(1, 44)=472.23$, $MSE=0.50$, $p<.001$, $\eta_p^2=.92$. Neither a main effect of background sound nor an interaction was found, $F(1, 44)=2.49$, $MSE=0.32$, $p=.122$, $\eta_p^2=.05$, and, $F(1, 44)=0.09$,

$MSE=0.27$, $p=.772$, $\eta_p^2=.002$, respectively. For conditions without interruptions, mean writing speed was higher in silence compared to background speech, $F(1,44)=4.22$, $MSE=0.27$, $p=.046$, $\eta_p^2=.09$, but there was no main effect of time interval, $F(1, 44)=1.25$, $MSE=0.38$, $p=.270$, $\eta_p^2=.03$. Also, the interaction between time interval and background sound was significant, $F(1, 44)=6.62$, $MSE=0.25$, $p=.014$, $\eta_p^2=.13$. Follow-up *t*-tests were done to investigate the interaction between background sound and time interval. There was no difference between silence and background speech in the period called 'last 30 s before the interruption' (note that this condition had no interruptions), $t(44)=0.46$, $p=.649$. Writing speed was higher in silence compared to background speech during the period called '10 s after the interruption' (note that this condition had no interruptions), $t(44)=2.67$, $p=.010$.

Subjective ratings of workload
Figure 4 shows that workload was lowest in the silent condition without interruptions and highest in the background speech condition with interruptions. There was no difference in workload between the background speech condition without interruptions and the silent condition with interruptions. A 2(background sound: silence vs speech) × 2(interruptions: yes/no) ANOVA showed that workload was lower in silence (mean index score = 3.97) compared to background speech (mean index score = 4.67) and higher for conditions with interruptions (mean index score = 4.77) compared to the conditions without interruptions (mean index score = 3.87). These two main effects were significant. $F(1, 44)=63.78$, $MSE=0.57$, $p<.001$, $\eta_p^2=.59$, for interruptions, and, $F(1, 44)=31.63$, $MSE=0.70$, $p<.001$, $\eta_p^2=.42$, for background sound. No significant interaction was found, $F(1, 44)=2.80$, $MSE=0.54$, $p=.102$, $\eta_p^2=.06$. Follow-up *t*-tests showed differences in subjective workload between all conditions, all $t>3.00$, except for the difference between 'speech without interruptions' and 'silence with interruptions'.

Discussion

Participants experienced lowest workload when they worked in silence without being interrupted by other task-requests. Most workload was experienced when both background
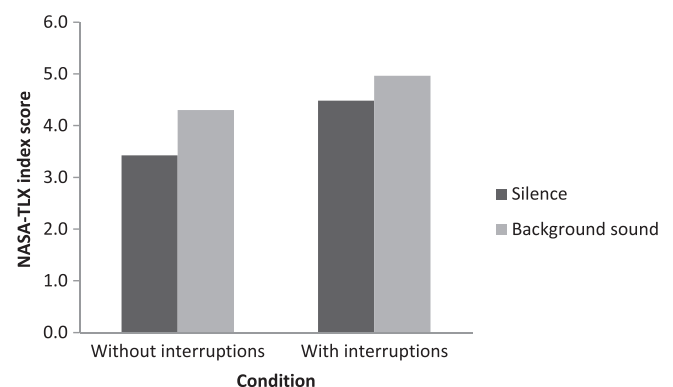

Figure 4. Nasa-TLX index score for the four different conditions: silence without interruptions; speech without interruptions; silence with interruptions; speech with interruptions

speech and task interruptions were present, while no differences in workload were experienced between the condition where participants worked with background speech only and the condition with task interruptions only. In the context of writing speed, task interruptions had a robust effect but background speech did not. Furthermore, no significant interaction between background speech and task interruptions was found in Experiment 1. This does not mean that background speech does not have any effect at all, but the effects were not as strong and clear-cut as expected. Moreover, generalizing the results from Experiment 1 to an applied context —such as the effects of background noise in open plan offices—should be made with care because the sound environment typically comprise other sounds than monologues.

EXPERIMENT 2

Experiment 2 was designed to obtain an arguably more ecologically valid view of the combined effects of task interruptions and background speech by the comparison of the effects of a dialogue (representing two colleagues talking to each other in the background) with the effects of a halfalogue (representing the voice overheard from someone talking on the telephone). Halfalogues and dialogues as background sound are common in open plan office contexts, such as call centers. As outlined above, a language-based task like writing is relatively sensitive to the disruptive effects of background speech because of the similarity of the processes involved in the writing-output task (e.g., retrieval from semantic long-term memory) and in the involuntary analysis of the meaning of the background speech signal. As dialogues overall contain more semantic information than halfalogues, and the speech stream unfolds during a more steady pace over time, a straightforward hypothesis would be that dialogues are more disruptive than halfalogues. However, Norman and Bennett (2014), Galván, Vessal and Golley (2013) and Emberson, Lupyan, Goldstein and Spivey (2010) exposed their participants to halfalogues and dialogues while the participants were conducting an anagram task (Galván et al., 2013), a reaction time task and a visual monitoring task (Emberson et al., 2010) or no task at all (Norman & Bennett, 2014). Self-rating measures of annoyance and distraction in these studies suggested, perhaps counterintuitively, that halfalogues are more disruptive than dialogues. However, it is still unclear whether halfalogues would be more disruptive than dialogues also in the context of a continuous, applied task such as word processed writing.

Methods

Participants
A total of 30 students (mean age = 23.7 years, SD = 3.20), amongst them six men, from the University of Gävle, Sweden, participated. Data from two participants were lost because of technical errors and they were discarded from the analyses. Hence, the final sample consisted of 28 participants. Participants received a small honorarium for their efforts.

Design
The design was a 2(Interruption: yes vs. no) × 3(Background sound condition: silence vs. dialogues vs. halfalogues) × 4 (Time period) within-subjects design. Hence, the experiment consisted of six conditions: one silent without interruptions (writing for 5 min), one silent with interruptions (writing for 1 min, followed by a task shift for 30 s, another writing period of 1 min, a task shift for 30 s, a third writing period of 1 min, a task shift for 30 s and a final writing period of 30 s), and another four corresponding conditions, two with dialogues and two with halfalogues instead of silence (Figure 1).

Apparatus and materials
Sound. Two different sound files were used as background speech, and another file which was used during a practice period in the writing task. These sound files were irrelevant to the task, and consisted of a dialogue, simulating a telephone conversation between a man and a woman talking about everyday life. In the halfalogue, the male voice of the dialogue was removed. The man and woman took turns continuously during the conversation, each talking for no more than about 5 s per person per turn. As the male voice was removed to create the halfalogue, the silent periods (approximately 5 s each) in the halfalogue corresponded to the length of the male voice in the dialogue. The conversation was recorded on a computer and presented to participants through headphones (Sennheiser HD 202) at approximately 68 dBA. The time length of each sound file was 5 min. The speech signal was presented continuously, without interruptions, over the whole experimental condition, so also in the condition with both background speech and interruptions (i.e., the speech signal was played back both during the primary task —word processed writing—and during the secondary task).

Writing task, interruption task and questionnaire. The writing task was identical to the writing task used in Experiment 1 except for two additional fairytale characters, as Experiment 2 comprised six conditions instead of four. The interruption task was identical to the interruption task used in Experiment 1. The questionnaire was identical to the questionnaire used in Experiment 1.

Procedure
The procedure was identical to the procedure in Experiment 1.

Results

Word processed writing
Figure 5 shows that writing speed was lower in the 'first 10 s immediately after the interruption had finished' for conditions with interruptions (mean = 1.66 characters/s) compared to conditions without interruptions (mean = 3.89 characters/s), but no differences for the other time intervals were found. In 'the next 5 s after', writing speed had returned to baseline level. Hence, it took 10–15 s for the participant to reach the same writing speed as in the period before the interruption started. Moreover, Figure 6 shows that writing speed per second in the time interval '30 s before

A

with interruptions
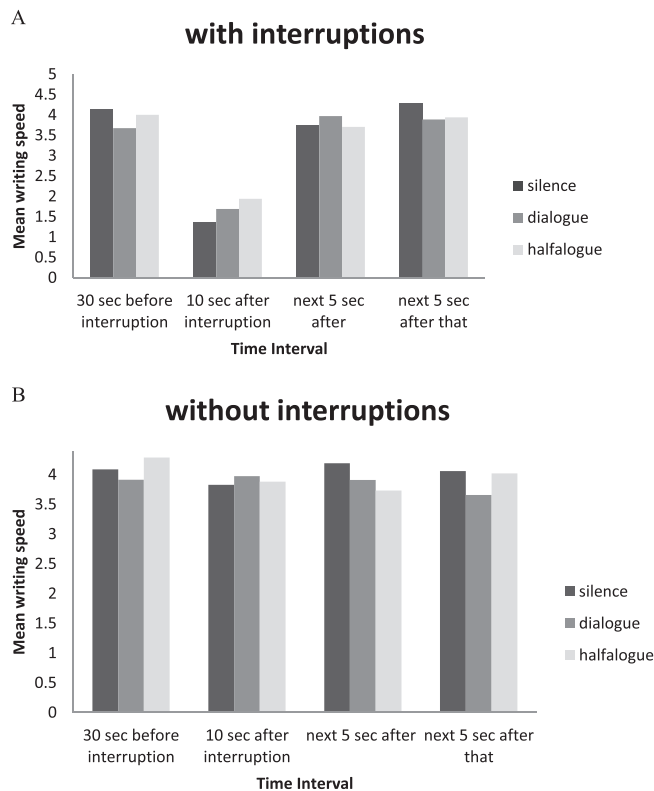

B

without interruptions

Figure 5. Mean writing speed (characters/s) for conditions in silence, with dialogue and with halfalogue as background sound at four different time intervals: last 30 s before interruption; 10 s after interruption; the next 5 s after and the next 5 s after that. The data for the same time periods in the writing task are reported both in conditions with interruptions (panel A) and in conditions without interruptions (panel B). Time periods in panel B correspond to the same time periods in panel A, and therefore carry the same name, but there was no task interruption in the condition reported in panel B
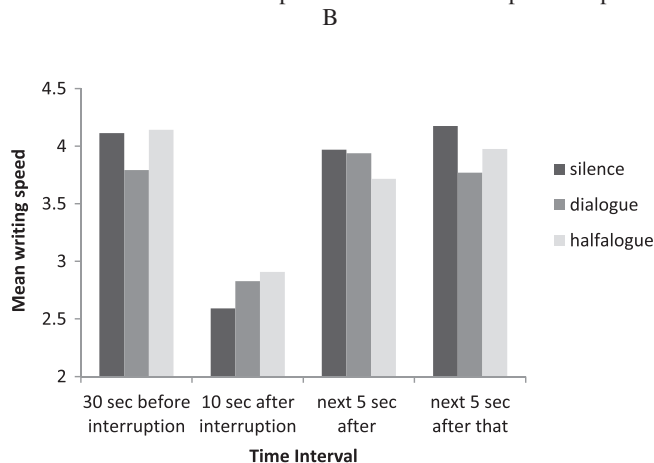

Figure 6. Mean writing speed (characters/s) for conditions with dialogue and halfalogue as background sound and in silence at four different time intervals: last 30 s before interruption; 10 s after interruption; the next 5 s after and the next 5 s after that. Conditions with and without interruptions are collapsed. Note that the Y-axis is truncated

interruption' was higher in silence and with halfalogues as background sound compared to a dialogue background sound. Hence, writing speed was lower at baseline when the background speech comprised two talkers in a dialogue.

A 2(interruptions: yes vs. no) × 3 (background sound: silence vs. halfalogues vs. dialogues) × 4 (time period: Time

interval: 30 s before the interruption, first 10 s after the interruption, next 5 s after, and the next 5 s after that) ANOVA, with writing speed as a dependent variable, revealed a significant main effect of interruptions, $F(1, 27) = 36.42$, $MSE = 1.66$, $p < .001$, $\eta_p^2 = .57$, and a significant main effect of time interval, $F(3, 81) = 87.19$, $MSE = 0.68$, $p < .001$, $\eta_p^2 = .76$. Significant interactions were found between time interval and background sound, $F(6, 162) = 2.59$, $MSE = 0.76$, $p = .020$, $\eta_p^2 = .09$, and between time interval and interruptions, $F(3, 81) = 59.56$, $MSE = 0.85$, $p < .001$, $\eta_p^2 = .69$. Comparisons between sound conditions reported in Figure 6 showed a significant difference between silence and dialogue, $t(27) = 2.84$, $p = .009$, an almost significant difference between halfalogue and dialogue, $t(27) = 1.88$, $p = .070$, and no significant difference between silence and halfalogue, $t(27) = 0.15$, $p = .879$. This indicates that dialogues were more disturbing than halfalogues, at least at time intervals distal to the interruption. Ten seconds after the end of the interruption, the difference between silence and dialogues disappeared.

Subjective ratings of workload

Figure 7 shows that workload was lowest in the silent condition without interruptions and highest in the condition with interruptions and dialogue as background sound. There were no differences between the silent condition with interruptions and the dialogue condition without interruptions. A 2 (Interruptions: yes vs. no) × 3(Background sound: silence vs. halfalogue vs. dialogue) ANOVA showed main effects for both background speech and task interruptions. Workload was lower in silence (main index score = 3.93) compared to both halfalogues (mean index score = 4.35) and dialogues (mean index score = 4.56), $F(2, 54) = 9.54$, $MSE = 0.61$, $p < .001$, $\eta_p^2 = .261$, and workload was lower in conditions without interruptions (mean index score = 3.84) compared to conditions with interruptions (mean index score = 4.71), $F(1, 27) = 42.19$, $MSE = 0.75$, $p < .001$, $\eta_p^2 = .610$. No significant interaction between background speech and interruptions was found, $F(2, 54) = 0.06$, $MSE = 0.34$, $p = .946$, $\eta_p^2 = .002$. A more detailed t-test analysis revealed significant differences between silence and halfalogues, $t(27) = 2.78$, $p = .010$, and between silence and
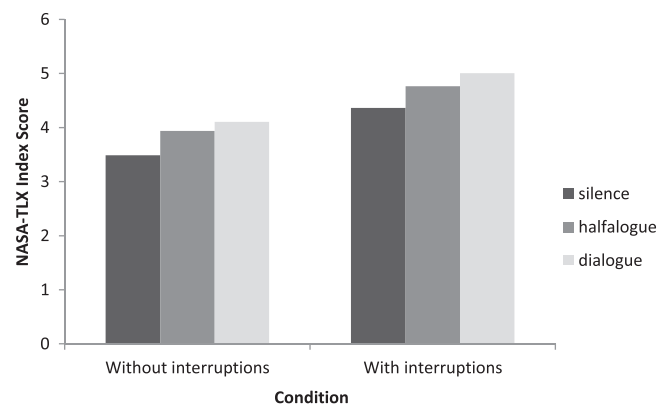

Figure 7. Nasa-TLX index score for the six different conditions: silence without interruptions; halfalogues without interruptions; dialogues without interruptions; silence with interruptions; halfalogues with interruptions and dialogues with interruptions

dialogues, $t(27) = 3.97$, $p < .001$. No significant difference was found between halfalogues and dialogues, $t(27) = 1.61$, $p = .119$.

Discussion

The results from Experiment 2 replicated the key-findings from Experiment 1, as they showed that interruptions have a disrupting effect on writing performance measured by writing speed at the time when the task is resumed after the interruption. Furthermore, the results from Experiment 2 also replicated the finding concerning the effects of background sound: Background speech makes it harder to reach higher writing speed levels compared to silent situations, at least continuous speech (dialogues), but not necessarily speech with many pauses interspersed (halfalogues). Experiment 2 also showed that dialogues were more disturbing than halfalogues, as seen in the subjective ratings of workload.

GENERAL DISCUSSION

The current experiments aimed to study the combined effects of background speech and task interruptions on word processed writing. In Experiment 1, for the conditions with interruptions, a large drop in writing speed occurred in the first 10 s after the interruption, but after the next 5 s, writing speed again reached baseline level. Hence, it took 10–15 s for the participants to regain full writing speed while they had resumed the writing task after the interruption. Background speech had only a small effect on performance: It appeared to prevent the participants from reaching higher levels of writing speed, but did not add to the writing-speed cost inflicted by task-interruptions. These results were conceptually replicated in Experiment 2. Moreover, Experiment 2 showed that dialogues were more disruptive than halfalogues, as revealed both in subjective reports of workload and in performance decrements.

The drop in writing speed during the period immediately after the interruption confirmed our expectations and supports the theory of situation awareness (Endsley, 1995) and attention reallocation (Trafton & Monk, 2008). One interpretation of the interruption effect is that participants had to shift attention from the interruption task, back to the writing task; and before they could continue writing, they had to re-read (or recollect) what they were doing and think about how to continue. The expectation that background speech, in conditions with interruptions, should add to the cost induced by the task-interruption was, however, not supported by the results. A possible explanation for this outcome is that the writing task, and the reorientation process, is so demanding and of such high cognitive load that it shields the participants from further disruption (cf. Halin et al., 2014; Hughes, 2014). Another possible explanation is, though, that floor effects made background speech unable to impair writing speed further, over and beyond that by task-interruptions. The opportunity for rehearsal during the interruption task was limited, as the mental arithmetic task, that filled the interruption interval, was arguably quite demanding and of sufficient length to prevent rehearsal. The arithmetic task should therefore have made it hard for the participant to remember and re-orientate on the writing task after the interruption. Hereby, writing speed was already at a very low level and could perhaps not be suppressed further by the background speech.

It is impossible to claim, on the basis of the data reported here, that the attention capture account or the interference-by-process account of noise effects receives more support than the other. Both theories can account for the data, either in isolation or in combination. For example, meaningful or interesting aspects in the background sound signal may have captured the participants' attention away from the writing task. Similarly, interference between the processes needed to write a text and the processes involved in the automatic analysis of the semantic information in the background speech may have prevented the individuals from reaching higher levels of writing speed. However, Experiment 2 showed that dialogues were more disruptive to writing than halfalogues were. From the viewpoint that halfalogues comprise more drastic physical changes in the sound stream than dialogues, as more silent periods are present in a halfalogue, and halfalogues may be more interesting to listen to than dialogues (Norman & Bennett, 2014), one would expect a halfalogue to be more potent at capturing attention than a dialogue would be (cf. Hughes, 2014). Yet, the results suggest that it is the dialogue that is the most disruptive; a result that may lend some support for the interference-by-process account over the attention capture account in view of the higher degree of marked physical changes in the halfalogue. It should be noted though, that dialogues are more physically changing in view of other aspects, such as the change in voice. It is therefore impossible to draw any firm conclusions about which of these accounts is the better explanation of the results reported here.

The finding that dialogues are more disruptive than halfalogues runs contrary to what was found in Emberson et al. (2010), Galván et al. (2013) and Norman and Bennett (2014). One possible explanation for the difference in results between these extant studies and the current study may be found in the task the participants conducted. In the extant studies, the participants were asked to conduct a visual monitoring task and a reaction time task (Emberson et al., 2010) or an anagram task (Galván et al., 2013) while being presented with a dialogue or a halfalogue, or they were not asked to conduct any task at all (Norman & Bennett, 2014). In all these studies, participants rated halfalogues as more annoying and distracting compared to dialogues; and performance on the tasks was lower with halfalogues compared to that with dialogues, except for the anagram task, where no differences between the sound conditions were found. A possible explanation for the greater disruptive power in halfalogues, posed by Emberson et al. (2010), is that halfalogues are less predictable than dialogues because of the missing content in halfalogues. Another possibility is that halfalogues trigger a higher 'need-to-listen' response, because of participants' interest in what is being said (Norman & Bennett, 2014). In the context of a language-based task, such as word processed writing, however, dialogues appear to be more disruptive than halfalogues, perhaps because dialogues contain more semantic information compared to halfalogues. As more semantic information will be processed

automatically in the dialogue, the dialogue will produce a greater degree of interference with similar processes engaged in the writing task. Moreover, the writing task is continuous, and therefore a brief switch of the locus of attention toward the background sound, and then back to the writing task, may not have such a large impact on overall performance. In the context of a reaction time task, conversely, even short attention switches can have relatively large effects on overall performance, because entire trials may be missed or response times substantially prolonged.

In view of the difference between tasks and dependent measures, it is worthwhile to note that the dependent measure of the current experiments—text writing speed—fails to reflect other important aspects of writing, such as the quality of the text (e.g., spelling, number of propositions, readability). There could, for example, be a tradeoff between writing speed and the quality of the text. A target for future studies could be to, besides the quantitative aspects of writing, analyze the qualitative aspects of the written texts, as that analysis could reveal a more complete picture of the effects of task interruptions and background speech on word processed writing.

Mental workload was lowest for the silent conditions without interruptions and highest for the conditions with interruptions and background speech in combination. Besides this, mental workload was lower for conditions in silence compared to background speech, and higher in conditions with interruptions in comparison with conditions without interruptions. This pattern was found in both Experiments 1 and 2. In Experiment 2, the presentation of dialogues resulted in a higher workload compared to halfalogues (although the difference did not reach significance). This is in line with the writing speed data and with our expectation, but, again, contrary to the results found in previous reports on the halfalogue effect (Emberson et al., 2010; Galván et al., 2013; Norman & Bennett, 2014). Although the writing speed data from both Experiments 1 and 2 only lent weak support for the assumption that background speech disrupts performance, several other studies have reliably shown that background speech disrupts writing (Keus van de Poll et al., 2014, 2015; Sörqvist et al., 2012), and the subjective data suggest that background speech adds to experienced workload. In that sense, the subjective ratings and the performance data matched. One possible reason for the slight discrepancy—the weaker effect of background sound in the context of performance measures compared to subjective ratings—is that experienced workload and annoyance can be compensated for, by trying harder, making the background speech unable to disrupt the quality of task execution. This compensation helps performance but, in turn, does not prevent background speech from having negative consequences for well-being and work satisfaction in the workplace.

Applied implications and concluding remarks
The results from this study are relevant for the scientific understanding of environments like schools and (open) offices and other environments where background sound and task-shifting are ineradicable. One conclusion from this study, to consider when designing open workplaces, is that halfalogues and dialogues can have different effects in different situations—maybe as a consequence of different task requirements among the office workers—as results of Experiment 2 suggest, in combination with the results reported by Emberson et al. (2010), Galván et al. (2013) and Norman and Bennett (2014). Even though the results in both Experiments 1 and 2 show that both background speech and task-shifting impair productivity and lead to costs to performance, perhaps the most intriguing finding from an applied point of view is that the cost of task-shifting was really low. In just 10–15 s, the writers were back at normal, producing texts at the same speed as before the interruption. However, a work situation with both background speech and task-shifting in combination is particularly disliked, which underlines the importance of silent work/school environments, especially when the characteristics of the job are such that task-shifting is unavoidable. In the long run, the relatively small task-interruption cost to productivity might be outweighed by its effect on annoyance and distress.

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