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Abstract

Interruptions in the form of instant messaging and multitasking are being normalized in the work environment, even though existing literature suggests that both negatively affect productivity. This might be due to attention residue: The persistent and intruding thoughts about the interruption during the next task. To test whether attention residue plays a role in the effects of instant messaging on productivity, the current study investigates whether instant messaging in a sequential- and multitask setting affects the occurrence of attention residue and tests for a moderating effect of task complexity. This is investigated by testing 91 participants' productivity, using a Lexical Decision Task (LDT), after they have been instant messaging. In this online study, half of the participants received sequential task- and half multitask-instructions for the LDT. The current study did not find that instant messaging in a sequential- and multitask setting affected the occurrence of attention residue during the second task and did not find a moderating effect of task complexity either. However, these findings are in sharp contrast to the existing literature and Threaded Cognition Model and combined with the limitations of an unsuccessful manipulation and a non-switching-multitask-group, make it difficult to interpret and generalize these findings.

The Occurrence of Attention Residue after Instant Messaging during Sequential- and Multitasking

The current society is full of distractions and interruptions. Not only in the private spheres, but also in work environments where people are being judged on their productivity (Pitichat, 2013; Vaast & Kaganer, 2013; Hassoun, 2015). David et al. (2015) found that people let themselves be interrupted more than they would like. This study found that when studying, only 60% of one's attention is directed towards one's studies. The great amount of distractions and interruptions form a problem in the current society, because they result in less productivity, which in turn leads to less free time, less job satisfaction and eventually less subjective wellbeing (Cropanzano & Wright, 2001; Grant, Christianson & Price, 2007; Csikszentmihalyi, 1997).

Beside the fact that people let themselves be distracted and thereby reduce their productivity by spending time on the interruptions, the distractions and interruptions also negatively affect their productivity during the time they spend on the task. Multiple studies suggest that distractions and interruptions lead to performance loss on the interrupted task, even when they controlled for the time spent on the interruptions (Gillie & Broadbent, 1989; Spira & Feintuch, 2005; Hagen, 1967). We will refer to this effect as carryover effect. This carryover effect even holds up for small interruptions, like opening one's email or doing something related to the interrupted task (Jett & George, 2003; Speier, Vessey & Valacich, 2003).

Nowadays, one of the most common forms of interrupting one's work is instant messaging (Pitichat, 2013; Vaast & Kaganer, 2013). Instant messaging can be viewed as real time chatting by sending and receiving messages using a technology-based device (Nardi, Whittaker & Bradner, 2000). Similar to the interruptions mentioned above, instant messaging has been shown to have negative effects on productivity (Fox, Rosen & Crawford, 2009; Mansi & Levy, 2013; Rosen, Carrier & Cheever, 2013), including the carryover effects (Altmann & Trafton, 2007; Leroy, 2009; Thornton et al., 2014; Leroy & Schmidt, 2016; Duplice, 2017). Gupta & Sharda (2008) revealed that a knowledge worker may lose 4–5% of their workday due to interruptions from arriving messages and this was in 2008! Since 2008, instant messaging has played a larger role in the work environment (David et al., 2015; Pitichat, 2013; Vaast & Kaganer, 2013) and is in some cases even becoming part of the job (Fox, Rosen & Crawford, 2009). That makes instant messaging a growing problem for productivity. To get a clearer insight in this problem, the current study will investigate how instant messaging affects productivity. It will especially focus on the carryover effects that arise, when someone performs a task and is instant messaging at the same time. In order to do this, we will look at sequential- and multitasking.

Performing two tasks consecutively is called sequential tasking (Buser & Peter, 2012; Fischer & Plessow, 2015). This means that receiving and responding to one message before resuming work is a form of sequential tasking. The problem with instant messaging, however, is that it never stops: One can always receive a new message. This means that when it comes to instant messaging, people do not just let themselves be interrupted once or twice, they are instead actively switching between their work and the instant messaging (Leroy, 2009; Rosen, Carrier & Cheever, 2013; Hassoun, 2015). This constant switching between tasks, without completing the first task before engaging in the second, is called multitasking (Buser & Peter, 2012; Fischer & Plessow, 2015). The problem with multitasking is that the decrease in productivity for multitasking is greater than the decrease in productivity for sequential tasking (Salvucci and Taatgen, 2008, 2010; Borst & Taatgen, 2007; Fischer & Plessow, 2015; Nagata, 2003; Hassoun, 2015). Some studies suggest that this is due to the carryover effects (Leroy, 2009; Duplice, 2017). Therefore, in order to get a better insight in the effects of instant messaging on productivity, we have to look at the carryover effects that arise from the constant switching between one task and the instant messaging. One theory to explain these carryover effects is attention residue (Leroy, 2009; Duplice, 2017).

Attention residue occurs when thoughts of a prior unfinished task persist and intrude while performing a second task. This manifests itself as less attention for a second task after switching from an unfinished prior task (Leroy, 2009; Leroy & Schmidt, 2016). The existing literature in attention residue states that if a prior task is unfinished, people perform worse (Speier, Vessey & Valacich, 2003; Leroy, 2009, 2011) and spend more time (Jett & George, 2003; Fox, Rosen & Crawford, 2009) on the second task. This indicates that attention residue could explain the carryover effects of instant messaging on productivity through a lack of attention. Even though this would provide a clearer insight in how instant messaging affects productivity, this has not yet been studied. That is why the current study will investigate this. Before the current study will be discussed, however, the theoretical substantiation of attention residue is discussed to see how and why attention residue occurs and affects productivity.

Attention residue can theoretically be substantiated with the Limited Cognition Model. This model states that humans have a limited capacity of taking in and processing information. Therefore, the Limited Cognition Model states that people cannot fully perform two tasks at the same time, because the maximum cognitive processing capacity (100%) would be divided over both tasks (50% each) (Simon, 1979; David et al., 2015). When two tasks need more than 50% of processing capacity accumulated, it would lead to cognitive overload when switching between these tasks. This cognitive overload will in turn result in productivity loss (Pool et al, 2000, 2003, cited in David et al., 2015).

The Threaded Cognition Model goes one step further than the Limited Cognition Model by stating that the switching between tasks comes at a price as well. It states that this switching between tasks comes at the cost of some processing capacity. Therefore, when someone is multitasking, he or she is constantly switching at the cost of having less processing capacity to focus on the tasks at hand. The maximum processing capacity (100%) would then be divided over three things: The two tasks and the constant switching (Salvucci and Taatgen, 2008, 2010; Borst & Taatgen, 2007). This model substantiates the theory of attention residue and would explain why multitasking, which includes constant switching, decreases productivity more than sequential tasking.

Some research found that the occurrence of attention residue is moderated by task complexity (Speier, Vessey & Valacich, 2003; Cades et al., 2008; Leroy & Glomb, 2018). Some studies found that that when a simple task is interrupted, performance loss was marginable, but that by increasing task complexity of the interrupted task, task performance on the interrupted task decreased and people spent more time. In other words, productivity on an interrupted task is affected by the complexity of that task (Kruglanski & Webster, 1996; Speier, Vessey & Valacich, 2003; Cades et al., 2008; Leroy & Glomb, 2018). This indicates that the occurrence of attention residue seems to be moderated by task complexity. This is also in line with the Threaded Cognition Model, since switching to and from a more complex task, would costs more cognitive processing capacity, because there are more factors to take into account when reengaging in a more complex task (Salvucci & Taatgen, 2008, 2010; Leroy & Glomb, 2018). Despite this existing literature and theoretical substantiation for the moderating effect of task complexity, there are studies that found the opposite effect. For example, a study by Sörqvist & Marsh (2015) found that with increased task complexity, concentration levels increased and attention was less likely to divert away. Other studies state that individual differences, like experience with multitasking, determine whether task complexity is likely to moderate the occurrence of attention residue and its' effects on productivity (Sörqvist & Rönnberg, 2014; Li et al., 2011). Because of this contrast in the existing literature, the current study will take task complexity into account for a clearer insight when interpreting the results.

Summarized, the current literature suggests that interruptions have a negative effect on productivity (Gillie & Broadbent, 1989; Spira & Feintuch, 2005; Speier, Vessey & Valacich, 2003). This is especially true for unfinished interruptions, like instant messaging, because of the carryover effects that result from the costs of the constant switching between tasks (Salvucci and Taatgen, 2008, 2010; Borst & Taatgen, 2007; Fischer & Plessow, 2015; Nagata, 2003; Hassoun, 2015). This means that the great amounts of instant messaging in the work environment (David et al., 2015; Pitichat, 2013; Vaast & Kaganer, 2013) forms a problem for productivity. In order to overcome this problem, it is important to understand how instant messaging affects productivity, especially the carryover effects. Attention residue could explain these carryover effects, but even though existing literature and theoretical substantiation deem this likely, this has not yet been researched. Neither can the existing literature provide a definitive answer whether task complexity moderates the occurrence of attention residue. That is why the current study will investigate the occurrence of attention residue after instant messaging and test for a moderating effect of task complexity.

In order to focus on the occurrence of attention residue, the current study makes a distinction between instant messaging during sequential- and multitasking. This has two reasons. First of all, attention residue occurs when thoughts of a prior unfinished task persist and intrude while performing a second task (Leroy, 2009; Leroy & Schmidt, 2016). With sequential tasking, one finishes the prior task before engaging in the second. By finishing the prior task, sequential taskers suppress the possibility of the persisting intruding thoughts to occur (Salvucci and Taatgen, 2008, 2010; Fischer & Plessow, 2015). When multitasking one does not finish the prior task, which makes it possible for attention residue to occur (Buser & Peter, 2012; Fischer & Plessow, 2015). The second reason for using sequential and multitasking is the difference in the amount of switching between tasks. According to the Threaded Cognition Model, attention residue occurs due to the carryover effects of the constant switching. Therefore, attention residue can only occur when multitasking. That is why the current study uses a design that compares a sequential tasking condition with a multitasking condition. To test whether attention residue can explain the carryover effects of instant messaging on productivity, both conditions perform an instant messaging and a productivity task. The conditions will only differ in sequential and multitask instructions while doing the performance task. The sequential instructions inform the participants that the prior task (the messaging-task) is finished, while the multitask instructions state that it is not and that they can be called back to the messaging during the productivity task. Since productivity consists of performance and time spent (time consumption) (Tangen, 2005), both will be measured for the clearest insight. Finally, the current study will investigate whether task complexity plays a moderating role here.

Based on the existing literature and theoretical substantiation, we expect that the participants with multitask instructions, compared to the participants with sequential tasking instructions, will (a) perform worse and (b) spend more time on the second task. Secondly, we expect that the effects of the first two hypotheses (a) and (b) will increase with increasing subjective task complexity (c).

Method

Participants

The total study comprised 135 participants of which 88 individuals completed the study and met the criteria. Two of the finished participants did not enter their age, but since age does not seem to play a large role in the current study, both have been included in the analyses. Three participants finished every task, but did not complete the study, therefore their manipulation-check-, and task complexity-data are missing. Since the rest of their responses are registered and do not seem to differ from the rest, all three have been included in the analyses. Combined with the 88 finished participants, a total of 91 participants have been included in the analyses (54 women; age range 18-79; M=30.5). Participants have been recruited by word of mouth, research websites, email and social media. Participants did not receive anything in return for participation. The only inclusion criterium of the study was fluency in Dutch, since the experiment was completely in Dutch.

Research Design

The current study investigates whether sequential- or multitasking between an instant messaging task and a second task affects the performance and time consumption of the second task. This design is used, because existing literature suggests that attention residue can only occur on the second task when the prior task is unfinished. This means that with sequential tasking, where a prior task is finished before engaging in the second, attention residue cannot occur. With multitasking, however, the prior task remains unfinished, which according to the existing literature and theoretical substantiation, will lead to attention residue. With this design, we can observe if attention residue occurs after multitasking with instant messaging to get a clear insight in why this is such a problem for productivity. The current study further investigates whether subjective task complexity can moderate this effect for a clearer insight in the mechanisms and consequences of attention residue. For productivity, the current study measures performance as well as time consumption for a better understanding of what attention residue affects.

Measures

lexical decision task. The current study uses a Lexical Decision Task (LDT), to measure performance and time consumption. An LDT has been used in other studies measuring attention residue as well (Leroy, 2009; Leroy & Schmidt, 2016). Within the LDT the participants are asked to classify multiple stimuli as words or non-words. The stimuli will take the form of multiple letters after each other that sometimes form a word and at other times do not. With every stimulus, the participants get 2000 milliseconds (two seconds) to respond, otherwise it will count as an incorrect response. Between stimuli, a fixation is shown for 250 milliseconds for the participants to recalibrate and refocus. The participants are asked to respond by pressing two keys on different sides of a keyboard with the left key meaning “word” and the right key meaning “non-word”. The participants are asked to answer correctly and as quickly as possible to measure both performance and time consumption. The LDT contains a set of each 60 sets of letters that have to be classified correctly as word or non-word. The LTD provides the researchers with two final scores: The amount of accurate responses (performance) and the time spent per response (time consumption). Both performance and time consumption are measured per participant individually and per condition.

Performance data that are provided by the LDT are the amounts of correct-, incorrect- and timed out responses. From these data, we calculated a performance-score according to the formula provided by the paper of Huibregtse, Admiraal & Meara (2002). This formula is not only the commonly accepted method for calculating the performance-score, but controls for sophisticated guessing and the ratio of hits and false alarms as well. It is constructed in a way that the score will have a range from 0 to 1 for clear interpretation (Huibregtse, Admiraal & Meara, 2002; Lemhöfer & Broersma, 2012).

Time consumption is measured in milliseconds and displays the mean time it takes each participant to respond to each stimulus. Time consumption is presented in mean time spent instead of total time spent for a clear interpretation.

subjective complexity scale. Subjective task complexity will be measured with the question: “Please state to which extent you experienced Task 3 (The word recognition task) as difficult on a scale of 1 (very simple) to 100 (very complicated).”. In this field it is common to use subjective measures of task complexity, which have been shown to be very comparable to objective measures (Kernan et al., 1994, cited in Li et al., 2011; Maynard & Hakel, 1997, cited in Li et al., 2011).

manipulation check. A manipulation check will be added in the form of one question. This question asks the participant to identify which instructions they received prior to Task 3.

There are three optional responses: Instructions of their own condition, instruction of the other condition and "I do not remember".

Procedure

In this online experiment, participants are first asked to turn off their phone or put it on silent as to not get distracted. All participants are then asked for their demographic data. On the next page, all participants are told that they have three tasks to complete: Chatting with a chat-bot (Task 1), chatting with a person (Task 2) and a word recognition task (Task 3). On the first task (Task 1), the participants enter a chatroom, where they are told that they are chatting with a chatbot. In reality, they will be answering some questions about homonyms that are made in advance. The topic of homonyms is chosen, because combined with the LDT, this makes for a believable cover story as a language study, in order to keep the actual aim of the study hidden. In Appendix 1, *Messaging part of the study,* all the questions and messages from Task 1 are shown. As seen in Appendix 2, *Messaging layout*, the messaging part of the study is made to look similar to a chatroom to evoke an instant messaging-feeling. After finishing Task 1, the participants are divided over two conditions: a sequential- and a multitask condition, both with different instructions about their continuation. The sequential condition will receive instructions that Task 2 (chatting with a person) will not take place, because there is no researcher online to chat with, whereby they finish the messaging part of the study and can therefore continue to Task 3. The multitask condition is told that a researcher is online to do Task 2, but that he needs some time to get things ready. Instead of waiting for this however, the multitask condition is asked to continue to Task 3 for efficiency reasons, but with the important note that they will receive a notification during Task 3, when the researcher is ready. In these instructions, it is made clear that upon receiving this notification, the participants are asked to immediately switch back to the messaging part of the study (Task 2). In order to make this manipulation believable, a red switch-button will be added to the bottom of Task 3, saying: "To Messages", through which the participants are able to switch. This button is only available for the multitask condition, since only they are told to switch. The instructions also state that Task 2 will be about the same topic (homonyms) as Task 1, to ensure that this prior messaging task will not feel like it is finished.

In reality, all participants continue to Task 3, without ever performing Task 2. Upon entering Task 3, the participants will perform the LDT. After finishing this, the participants are immediately asked to fill in the manipulation check- and task complexity-question. By continuing to the next page, the experiment ends and all participants receive a complete debriefing. In this debriefing, the participants in the multitask condition are told that they do not have to come back to Task 2 and receive an explanation of why they had to believe that during the study. All participants get a short explanation of attention residue and are given the opportunity to receive an email with the results of the study and further information. The latter happens on the final page of the experiment, in order to separate the email-addresses from the rest of the data immediately.

Data Preparation

During the manipulation check, nine participants reported that they did not know their instructions for the LDT and 10 participants registered the wrong instructions (the instructions for the other condition). It remains unknown whether the three participants, whose manipulation-check-data is missing, knew the right instructions as well. This indicates that for 22 (9+10+3) out of 91 participants the manipulation was or could have been unsuccessful. Excluding these 22 participants would not only lead to an immense loss of power, but also fail to control for estimated guessing. In other words, excluding these participants does not rule out the possibility of other participants that guessed their right condition, but were not aware of it during the LDT. Because of these reasons, all participants were included in the analyses. Since all 22 participants have been included in the analyses, interpreting the conclusions derived from this data should be handled with care.

Additionally, five participants had a performance-score that was more than three standard deviations away from the mean. These five outliers have been excluded from these analyses.

Results

Randomization Checks

Using a Chi-Square test (χ^2), we tested the equal distribution of gender over the two conditions. The assumptions for the Chi-Square test were not violated, since condition and gender are both categorical variables and there were no expected values lower than 5. The results of the Chi-Square test showed no significant difference in gender ratio, even though this was only marginally, χ^2 (1) = 3.67, p = .055. The sequential condition contained 30 women and 13 men, whereas the multitask condition held 24 men and 24 women.

Using an independent sample t-test, we tested differences in age between the conditions. The assumption of equal variances was checked with the Levene's test and not violated. However, the assumption of normal distribution, checked with the Shapiro Wilk-test, was violated. The Shapiro Wilk-test showed that age was not normally distributed, but right skewed W (89) = .652, p < .001. Since age does not seem to play a large role in this study, we have to take this into consideration, but not stress it too much. The results of the independent sample t-test showed that the conditions did not significantly differ in age t (89) = .738, p = .462. In other words, the average age of both conditions appears to be distributed equally over the sequential condition (M = 32.6, SD = 18.3) and the multitask condition (M=30.0, SD = 15.7).

MANOVA

Using a MANOVA, we tested whether condition influenced performance and time consumption. *Table 1* shows the means and standard deviations of performance and time consumption for both conditions. The assumption of normal distribution was checked with the Shapiro Wilk-test and was met for both performance and time consumption. Note that for Performance this assumption was only met after the five outliers were excluded. The assumption of linearity was checked with a scatterplot combined with Pearson's correlation and was not violated either. The assumption of homogeneity of variance and covariance were tested with a Levene's test and a box-test respectively. Both assumptions were not violated. The results of the MANOVA showed no significant effect for condition on performance and time consumption, Wilks' Λ = .995, F (2, 83) = .194, p = .824. Univariate tests show that the two conditions do not differ on performance F (1, 86) = .09, p = .762, nor time consumption F (1, 86) = .24, p = .625. This indicates that condition did not affect the performance and time consumption on the LDT. This is not in line with the hypotheses stating that the participants with multitask instructions will perform worse (a) and spend more time (b) on the second task than the participants with sequential tasking instructions.

Condition	Average Performance-Score	Average Time Consumption
Sequential	0.73 (0.10)	894.0 (117.7)
Multitask	0.74 (0.11)	905.8 (105.7)

Table 1. Average Performance-Score and Time Consumption (in milliseconds) on the LDT with Standard deviations for the Sequential- and Multitask Condition.

Moderation

Using a Process moderation analysis, we tested for an interaction effect of task complexity and condition on performance, as well as time consumption. First the assumption of homoscedasticity was checked with a plot and appeared unviolated. Secondly, the assumption of normal distribution and uncorrelated residuals were tested using a Durbin-Watson test combined with a histogram. These showed that both assumptions were not violated. Finally, the assumption of linearity, tested with a scatterplot combined with Pearson's correlation, appeared not to be violated either. This meant none of the assumptions were violated. The results of the Process moderation analysis showed no interaction effect of task complexity and condition on performance, $b = .001$, $t(68) = 1.31$, $p = .195$. This is not in line with the hypothesis stating that the effects of instructions (sequential- or multitask) on performance of the first hypothesis (a) will increase with increasing subjective task complexity (c). Furthermore, the results of the Process moderation analysis showed no interaction effect of task complexity and condition on time consumption either, $b = 1.22$, $t(68) = 1.08$, $p = .285$. This is not in line with hypothesis stating that the effects of instructions (sequential- of multitask) on spent time of the second hypothesis (b) will increase with increasing subjective task complexity (c).

Conclusions & Discussion

In the current study we investigated whether instant messaging in a sequential- and multitask setting affected the occurrence of attention residue during the second task. We also tested for a moderating effect of task complexity. The results did not indicate that instant messaging in a sequential- and multitask setting affected the occurrence of attention residue during the second task. Neither did they show a moderating effect of task complexity. Both these findings are not in line with the hypotheses. The two findings are compared to the existing literature and Threaded Cognition Model and similarities and discrepancies are discussed.

The first finding of the current study is that performance and time consumption were not affected by whether someone was multitasking or sequential tasking. This indicates that attention residue does not occur when multitasking between instant messaging and a second task. On the one hand, this finding is in line with a small part of the existing literature that states that multitasking does not affect performance (Fox, Rosen & Crawford, 2009) and that multitasking only affects performance and efficiency for individuals with a preference for sequential tasking (Li et al., 2011). On the other hand, this finding is not in line with most of the existing literature that states that performance on a second task decreases and time consumption increases when a prior task is unfinished (Speier, Vessey & Valacich, 2003; Fox, Rosen & Crawford, 2009; Leroy, 2009, 2011, Leroy & Schmidt, 2016). Nor is it in line with the literature stating that the possibility of an interruption could lead to performance loss and an increase in time consumption (Jett & George, 2003; Speier, Vessey & Valacich, 2003; Thornton et al., 2014). Especially if this interruption takes the form of instant messaging (Fox, Rosen & Crawford, 2009; Mansi & Levy, 2013). Additionally, this finding is not in line with the current literature stating that multitasking leads to performance loss and an increase in spent time (Fischer & Plessow, 2015; Nagata, 2003; Hassoun, 2015). Finally, this finding is not in line with the Threaded Cognition Model that states that switching between tasks comes at a cost of less processing capacity (Salvucci and Taatgen, 2008, 2010; Borst & Taatgen, 2007).

The discrepancy between this finding and the existing literature and Threaded Cognition Model, could first of all be explained by the unsuccessful manipulation. The manipulation was the only difference between the two conditions and consisted of different instructions before the LDT, instructing them to sequential- or multitask, and the presence of a red button in the multitask condition that allowed them to switch. Failing to know what instructions one had, would therefore make his manipulation unsuccessful. This was the case for 22 out of the 91 participants. That is 24%! Because participants from both the sequential and multitask condition had unsuccessful manipulations, we cannot state that the two conditions differed from each other. The lack of difference between the two conditions could explain why the two conditions did not differ in performance and time consumption and therefore explain the discrepancy between the current study and existing literature and Threaded Cognition Model.

A second explanation of this discrepancy is that performance and time consumption are measured with an LDT, which maintains a very shorts response time. An LDT provides the participants with only 2000 milliseconds (two seconds) to respond to every cue, before showing the next cue. Since attention residue occurs when thoughts of a prior unfinished task persist and intrude while performing a second task (Leroy, 2009; Leroy & Schmidt, 2016), the short response time could have suppressed the possibility of these thoughts to persist and intrude during the LDT. Therefore, the short response time of the LDT might have suppressed possibility of attention residue to occur, which could explain the mentioned discrepancies.

The second finding of the current study is that we did not find that the difference in performance and efficiency between multi- and sequential tasking varied by perceived task complexity. This indicates that subjective task complexity does not moderate the occurrence of attention residue during multitasking. On the one hand, this finding is in line with a small part of the existing literature stating that with increased task complexity, concentration levels increase and attention is less likely to divert away (Sörqvist & Marsh, 2015) and that individual differences like preference and experience determine whether task complexity is likely to affect performance and time spent (Sörqvist & Rönnberg, 2014; Li et al., 2011). On the other hand, this finding is again not in line with most the existing literature that states that that the occurrence of attention residue is moderated by task complexity (Speier, Vessey & Valacich, 2003; Cades et al., 2008; Leroy & Glomb, 2018) and that performance decreases, while time consumption increases when the complexity of the interrupting task increases (Speier, Vessey & Valacich, 2003; Cades et al., 2008). Finally, this finding is not in line with the Threaded Cognition Model. This model states that switching between tasks comes at a cost of less processing capacity (Salvucci and Taatgen, 2008, 2010; Borst & Taatgen, 2007). If we follow this model, increasing task complexity would increase the amount of processing capacity it takes to fully emerge in the second task and thus decrease the amount of processing capacity left over for the second task, resulting a a decrease in performance and an increase in spent time (Speier, Vessey & Valacich, 2003; Cades et al., 2008).

This discrepancy could be explained by the oversimplified way task complexity is measured. In the current study, task complexity was measured with only one question and near the end of the experiment. Since *subjective* task complexity was measured, all sorts of response biases could have influenced the subjective task complexity in the current study, reducing the score's validity. For example, neutral responding, the demand bias and social desirability. Even though it is common to use subjective measures of task complexity in this field and it has even been shown to be very comparable to objective measures (Kernan et al., 1994, cited in Li et al., 2011; Maynard & Hakel, 1997, cited in Li et al., 2011), asking only one question is an oversimplification with a low validity. Moreover, since this question was measured after the LDT, some participants could have justified their poor performance on the LDT by stating that they experienced the task as very complex. Even though they knew that the data were anonymized, they could have justified it for themselves. Because of this oversimplification in measuring task complexity, we cannot rule out factors that might have influenced the measurement, which could explain the found discrepancies.

A second explanation for the found discrepancies is the omnipresence of instant messaging and multitasking nowadays. Because multitasking and especially instant messaging has become so regular nowadays, people have a lot of experience with the two

(Pitichat, 2013; Vaast & Kaganer, 2013; Hassoun, 2015). This experience might make the attention residue effect disappear. Someone could for example, due to his experience, be able to switch at lower costs between tasks or close himself off for persistent and intruding thoughts of a prior task while performing the second. There are even studies that found that experience and individual preferences could reduce the negative effects of multitasking (Sörqvist & Rönnberg, 2014; Li et al., 2011). In the current study, the participants were for the most part from an age group that has a lot of experience with instant messaging and multitasking (Carrier at al., 2009; Wallis, 2006). If this could have affected the occurrence of attention residue, the multitask condition would have performed better than expected, whereas the sequential condition would have performed the same. This has been found. Therefore, if the above is the case, not task complexity, but experience would moderate the effects, which could explain the found discrepancies. More research will be needed however to test whether experience derived from the omnipresence of instant messaging and multitasking could affect the occurrence of attention residue.

Besides the explanations for the discrepancies between the findings in the current study and the existing literature and Threaded Cognition Model, the current study had two major limitations.

The first limitation of the current study is the unsuccessful manipulation. For a more extensive explanation, see the first explanation for the found discrepancies. This is not only an explanation for the found discrepancies however, but also a limitation of the complete study, because it suggests that the two conditions might not differ from one another. Since all the conclusions of current study assume that the conditions differed from each other, all these conclusions could be retrieved. This limitation could be overcome in future research by making the instructions clearer and make the participants confirm what their instructions are, before they can continue to the LDT. This way, all participants would know their instructions and can it be assumed that the conditions differ from each other.

The second limitation of the current study is that the participants in the multitask condition did not actually switch between tasks, but only had to opportunity to. This means that the participants in the multitask condition were not “actually multitasking”, because the constant switching is the difference between sequential- and multitasking (Buser & Peter, 2012; Fischer & Plessow, 2015). According to the existing literature, attention residue occurs after and because of the switching between tasks, due to the persistent and intruding thoughts of the prior task during the second task (Leroy, 2009; Leroy & Schmidt, 2016). According to the Threaded Cognition Model, attention residue originates from the costs in processing capacity from the switching (Salvucci and Taatgen, 2008, 2010; Borst & Taatgen, 2007). Therefore, because the participants did not actually switch between tasks, persistent and intruding thoughts of a prior task might not have occurred, suppressing the possible occurrence of attention residue. This could explain the found discrepancies, but is also a limitation of the current study. Because the participants in the multitask condition did not "actually multitask", they do not differ from the sequential condition. Since all the conclusions of current study assume that the conditions differed from each other, all these conclusions could be retrieved. On the other hand, the multitask condition did get instructions to perform two tasks at the same time and persistent and intruding thoughts of the prior task during the second task could still have occurred because of these instructions. Even though the Threaded Cognition Model states that the switching between tasks comes at the costs of less processing capacity, the instructions that the participants could at any moment switch back to the prior task, might have costed some processing capacity and might have allowed persistent and intruding thoughts of the prior task to persist and intrude. In this way, even without the switching, the two conditions could have still differed from each other and we should therefore not retrieve the conclusions so quickly. Nevertheless, the lack of switching in the multitask condition remains a limitation of the current study. This limitation could be overcome in future research by letting the participants have an instant messaging conversation while performing a second task that tests their productivity at the same time. This might be difficult to do with an LDT, but if the participants are allowed to pause it, an LDT could be used. Another possibility is that the future research divides the LDT into smaller parts, filling the breaks with instant messaging to make sure that the participants are switching and thus "actually multitasking". This final possibility makes it easier to control for time spent on the messaging.

The Occurrence of Attention Residue after Instant Messaging during Sequential- and Multitasking

The current study did not find that instant messaging in a sequential- and multitask setting affected the occurrence of attention residue during the second task. Nor did it find a moderating effect of task complexity. However, the unsuccessful manipulation and the lack of switching between tasks, make it difficult to interpret and generalize these findings. Besides the limitations, these findings are for the most part in sharp contrast to the existing literature and Threaded Cognition Model. Future research will be needed for better insight in the occurrence of attention residue when multitasking between instant messaging and a second task. Unfortunately, much remains unclear about the growing problem of interruptions in the form of instant messaging and its effect on productivity.

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Appendix 1. ***Messaging part of the study***

- Welkom in de chatruimte met BOT1026. Zeg gerust gedag.
    - Tekst invullen
- Hallo, ik ben BOT1026. Ik ben geprogrammeerd om te chatten en te leren. Ik leer het liefst over ambigue woorden en homoniemen.
- Wat weet u al van homoniemen?
    - Tekst invullen
- Heel goed! Wist u ook dat homoniemen één van de belangrijkste manieren is waarop programma's met kunstmatige intelligentie een taal leren?
    - Tekst invullen
- Dat komt doordat de context en zinsopbouw de definitie bepaalt. Dat gaat bijvoorbeeld op de volgende manier: Typ maar eens een volledige zin met het homoniem "Naar".
    - Tekst invullen
- "Naar" komt drie keer voor in mijn database. Welke definitie bedoelde u hier?
    - Bijvoeglijk naamwoord/bijwoord. Beschrijving van een onaangename, vervelende staat. Synoniem voor "Akelig"
    - Voorzetsel. Te gebruiken om een richting aan te geven.
    - Voorzetsel/voegwoord. Volgens het voorbeeld van. Synoniem voor "Zoals"
- Dank voor de feedback! Door de combinatie van zulke menselijke zinnen en de juiste definitie, kan ik snel een taal leren!
- Zou u meer homoniemen kunnen opnoemen behalve het woord "Naar"? U kunt deze woorden scheiden door middel van een komma. (,)
    - Tekstvlak openlaten
- Heel goed!
- Dank voor het gesprek!
    - Tekstruimte om te antwoorden. *Als geen reactie, na 7sec automatisch doorgaan naar volgende taak.*

Appendix 2. ***Messaging Layout***

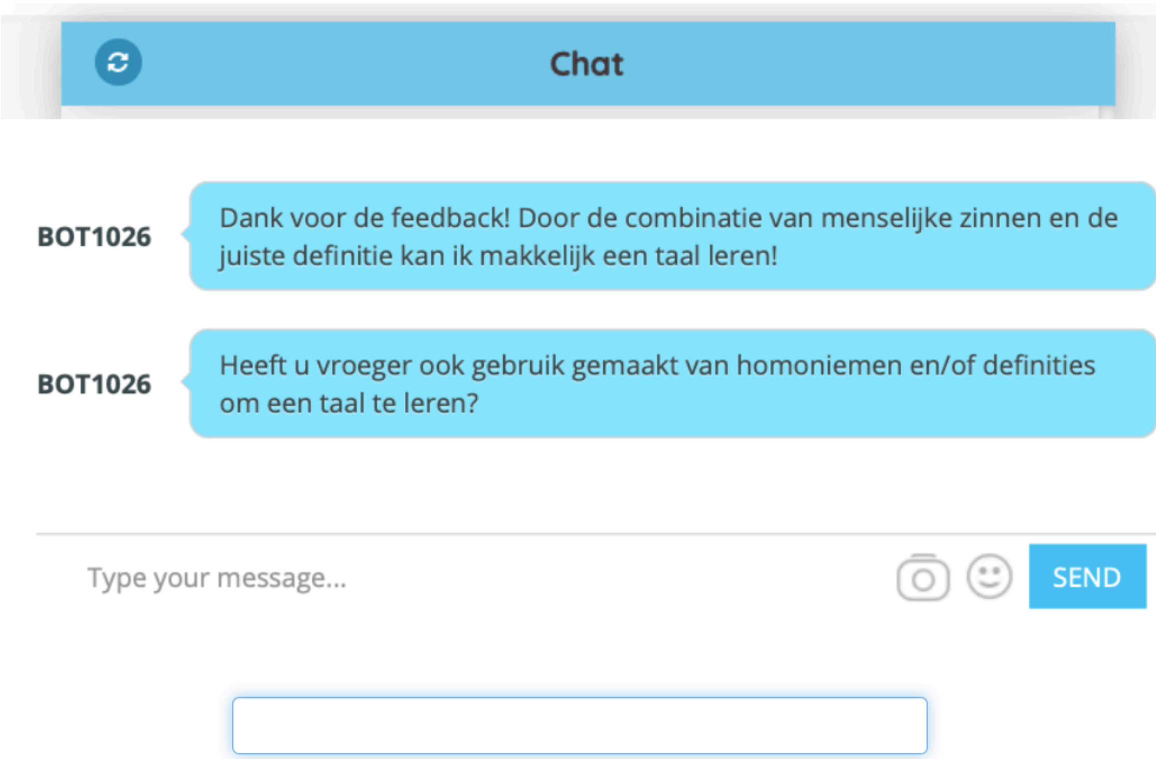

Figure 1. Messaging Layout.