The Effect of Anticipation of Reward on Semantic Processing: An N400 Study

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Abstract

Learner's motivation is regarded as an important feature of effective education. Behaviouristic teaching methods in schools make use of (anticipation towards) rewards and punishments to stimulate appropriate behaviour and motivation. This study aims to clarify how a reward anticipation modulates the cognitive strategy of semantic processing, by means of the N400-ERP as neural correlate for recognition of semantic incongruences. EEG-recordings were made of 37 women while they were asked to read 50 low-cloze and 50 high-cloze sentences. Then, participants completed a test in which the last word of the just read sentences was omitted and had to be filled in again. Half of the participants were told that for each right answer at the test their financial compensation for participation would increase. The paradigm induced strong N400-responses in both conditions. Upon further analysis, it was found that the effect sizes of individual electrode N400-responses were lower in the group that had a reward prospect, but there was no statistical difference. Nevertheless, the reward prospect group obtained significantly higher test scores. This test score showed a negative correlation with the strength of the N400 response. Therefore, a reward anticipation probably causes a qualitative shift in cognitive processing, away from meaningful semantic processing to strategies that promote direct, short-term rote learning. Attention must be paid in learning situations that require meaningful learning, as reward prospects might lead to short-term benefits at the possible cost of long-term deep understanding.

Keywords: N400-ERP, reward anticipation, rote learning, semantic processing.

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A strong presence of student's motivation for learning is thought to be a prerequisite for effective education (Dev, 1997). A lack of motivation for learning can account for decreased school performance and, eventually, drop-out (Hardre & Reeve, 2003). Therefore, stimulating, maintaining and regulating motivation of students can be seen as a core competence of a teacher (Skinner & Belmont, 1993). However, although motivation is a widely understood and valued concept, there are a large number of psychological theories on motivation (Covington, 2000). These theories attribute motivation to different properties and causes and tend to only partially overlap. Kim (2013) proposed a tentative model of motivation, combining insights from the psychological theories with actual behaviour on the one hand and the neural level with neural network behaviour on the other. Based on this model, he stated that rewards are crucial for promoting the student's learning motivation. However, it is yet unclear *how* the intended reward influences the cognitive processing strategies, which ultimately result in school performance. A better understanding of these effects could, in time, result in a more effective use of reward strategies to promote student learning and is therefore the scope of this study.

Rewards

The idea of giving rewards to learners to enhance motivation and performance is not new. Attribution of rewards has been common practice to stimulate behaviour of others in the desired direction throughout history all around the globe (Baldwin & Baldwinn, 1986, Bandura, 1969; Bushardt, Glascoff & Doty, 2011). The origin for the modern way of thinking about rewarding as a way to acquire positive behavioural effects in classrooms, stems from the operant conditioning experiments as performed by Skinner (1938). These experiments, in which behaviour of test subjects was modified by appealing to the natural function of the innate reward systems, provided experimental support for the first educational instructional design theory; behaviourism (Watson, 1913). This theory is nowadays seen as outdated and has been replaced by new learning theories (Reiser, 2001), such as cognitivism. Cognitive theorists critiqued behaviourism by noting that rewarding shown behaviour is merely a way to improve task attention and motivation; thereby indirectly affecting the actual behaviour, instead of directly changing behavioural choices (Neisser, 1967). However, some aspects of behaviourism are still visible and widely used in the society of today (Staddon, 2014). Our grading system at schools is an outing of this residual presence as it can be regarded as a way to offer a reward prospect for the shown behaviour of learning (Guskey, 1994). However, despite the clearly described behavioural effects of rewarding previously shown behaviour, it is not yet entirely clear how *anticipation* towards a reward affects the cognitive processing strategies underlying such behaviour.

Reward Anticipation

Cognitive processing takes place in several parts of the cerebral cortex. The innate reward system is based in the basal ganglia, but it receives this cognitive processing output to determine the appropriate action (Kandel, Schwartz & Jessell, 2000). Before behaviour is executed, both information streams from the basal ganglia itself and from the cerebral cortex are combined and weighed in the basal ganglia (Chakravarthy, Joseph & Bapi, 2010). Anticipation of a reward has been shown to enable a modulation of the cognitive processing signals in the basal ganglia (Kawagoe, Takikawa, & Hikosaka, 1998; Kirsch et al., 2003; Knutson, Adams, Fong, & Hommer, 2001). However, little is known about the potential effect of a reward prospect on cognitive processing itself (i.e. at the moment of processing, instead of modulating the processing result). In light of the discussion concerning the merits and benefits of rewards and reward prospects in classrooms and other learning environments, more knowledge is required about the interplay between anticipation towards reward, cognitive processing and behaviour. As the use of rewards still prevails in educational settings, it is necessary to continue providing a strong, neural understanding of cognitive processing and accompanying behaviour to clarify the educational effects of these rewards.

Semantic Processing

One possibility for studying cognitive processing is by investigating the semantic processing system of the brain by means of an electroencephalogram (EEG). This system is responsible for, amongst others, understanding concepts and giving meaning to incoming stimuli and is therefore seen as part of the explicit, declarative memory (Bookheimer, 2002; Kutas & Federmeier, 2011). Activity regarding this form of processing has been found to have a measurable neural correlate in the form of the N400-event related potential (ERP), as measured by an EEG (Kutas & Hillyard, 1980a; 1980b; 1980c). The N400-response, recorded approximately 400 milliseconds after a stimulus is noticed by the brain, is a measure for the effect of semantic violation processing (spoken or read). The N400-effect equals therefore the difference in N400-ERP between regular semantic processing and semantic violation processing. This has been elegantly shown in research by Kutas & Hillyard (1980a), where sentences were presented in which the last word ranged from a low-cloze probability (very unlikely, e.g. *On the swing sat a house*) to a high-cloze probability (very likely, e.g. *On the swing sat a child*). Moreover, the N400-effect showed to be elicitable by showing words that opposed the participant's mood (Chung, 1996). Lastly, it was found that a negative mood could strongly reduce the N400-response (Chwilla, 2011; Immordino-Yang & Damasio, 2007). Together, these findings show that semantic processing is influencable by the brain's limbic system, which is also called the 'emotional brain' and the source of both mood and reward (Morgane, Caller & Mokler, 2005).

Furthermore, semantic processing of incongruent stimuli and thus the presence of an N400-response, is also likely to be dependent on attention. This is because attention is required to notice an incongruence (Deacon, 1991 ; Kutas & Hillyard, 1989; Rugg, Furda, &

Lorist, 1988). As said earlier, the prospect of a reward is often used as a means to evoke motivation and attention and is therefore likely to provide an N400-effect. It is to be expected that foreseeing a reward will lead to an increase in attention, as mediated by the dopamine reward system (Schultz, 2013), as the reward system subserves to steer behaviour towards obtaining reward or avoiding punishment (Ressler, 2004). This means that anticipation of a reward could be reflected in neural measures of semantic processing, such as the N400-effect, and that this effect leads to enhanced cognitive performance.

Study Goal

Summarizing, this study will answer two questions. The first question addresses whether the reward prospect, in comparison to baseline, shows an increased N400-effect. Secondly, this study will examine whether an increased N400-response leads to an enhancement of rote learning test scores. Combined, these answers provide a better understanding of the effects of reward on cognitive processes and performance. This knowledge will aid to a more adequate use of reward incentives, explicitly regarding learning situations.

Methods

Participants

For this study 37 female, right-handed participants (age M = 21.8; SD = 5.7) were recruited. Both female (Federmeier, Kirson, Moreno & Kutas, 2001) and right-handedness (Szaflarski, Binder, Possing, McKiernan, Ward, & Hammeke, 2002) were necessary for a homogenous N400-measure. Furthermore, participants were not allowed to have mental or neurological disorders, chronic diseases or a history of drug abuse. Participants enrolled via a call for volunteers for EEG-research and were financially compensated.

Procedure

Participants were told that this study investigates the learning mechanisms and their underlying brain responses. After inclusion, the participants were randomly divided in two conditions; no prospect (control) and reward prospect. All participants were told that they had to carefully read and remember the shown sentences on the screen. Then, they were told that a test had to be made to make sure that the participants would pay attention. In the ‘no prospect’ condition, participants were told no more. However, in the ‘reward prospect’ condition, participants were told that the financial compensation they acquired would increase for every right test answer with €0.25. This way, the initially promised compensation of €5 could increase up to €10. After this explanation, the EEG-cap was mounted and the reading task was started, followed by the test. After the test, the test was scored and debriefing took place. In this debriefing the participants were explained what the goal of the study was and that they all received the maximal compensation of €10, regardless of the test results. Lastly, participants were asked to remain silent about this study towards peers.

Rote Learning Test

In this test, twenty sentences were selected from the reading task, with a randomization of high-cloze and low-cloze sentences. However, the last word of these sentences was omitted. Participants were asked to complete the sentences with the same words as provided during the readings task. Each right answer was worth one point. No interobserver reliability measures were calculated, as a clear answer sheet was present.

Data Acquisition and Analysis

EEG-task software (E-Prime 2.0) was used to program 100 declarative Dutch sentences, derived from Nieuwland & van Berkum (2006). In order to obtain reliable ERP-results, the defining word in these derived sentences, causing the congruence or incongruence, was placed at the end of the sentence. This way, sentences were made appropriate to speak of low cloze probability sentences and high cloze probability sentences (Connolly, 1994). These sentences were randomly presented word by word on a computer screen. Each sentence was preceded by a fixation cross (2600 ms), followed by a 300 ms blank screen. The final word duration was 600 ms, whereas other words in the sentence ware shown for 345 ms with 200 ms blank screen intervals. Total duration of the task was 17 minutes.

An elastic electrode cap (Biosemi Active 2 System) with 32 Ag-AgCl electrodes were mounted, with an electrode impedance kept below 50 kΩ during measurements. Furthermore, five referencing electrodes were placed around the eyes and on the mastoids to correct for eye blinks and other eye movements. The signals were amplified and digitized online at 2 kHz. The Fieldtrip application for Matlab was used to import the raw data (Oostenveld, Fries, Maris & Schoffelen, 2011). Before analysis, data was filtered through a 0.5-40 Hz band-pass filter. The data were now corrected on the mastoid reference electrodes.

Preparation of the raw data for analysis was also done in Matlab with a Fieldtrip application, which sampled the data down to 0.5 kHz. The first step was to correct the data for eye blinks and horizontal and vertical eye movements via the Independent Component Analysis method (Jung et al., 2000). Second, the recording of each individual electrode was searched for measurement artefacts. This way, electrodes that produced irregular or deviating signals from all other channels could be marked and excluded. After exclusion, data from surrounding channels was used to recalculate the excluded channel. Therefore, two neighbouring electrodes were never excluded together. Third, all 100 trials were segmented from 100 ms prestimulus (stimulus is the last, critical word of the sentence) to 1 sec poststimulus, resulting in 50 high-cloze and 50 low-cloze trials. Each trial was again manually screened for artefacts, such as deviation from referencing electrodes and evident irregular patterns. Measurements with more than 20 excluded high-cloze or low-cloze trials were completely excluded from the study. As a result, EEG-recordings of two participants were not included in the final analyses, resulting in 35 participants for analysis. Out of 50 trials, a mean of 13.9 (*SD* = 5.1) and 14.7 (*SD* = 4.7) trials were excluded in the high-cloze and low-cloze groups, respectively.

Analyses were restricted to the C3-, Cz-, C4-, CP1-, CP2-, P3-, Pz- and P4-electrodes, as Chwilla (2011) showed that these midline electrodes provide the best signal to investigate the low/high-cloze effect. For mean ERP calculations, averages for high-cloze and low-cloze responses were aligned to a 100 ms baseline period preceding the critical word. The N400 window was defined as 300 ms to 500 ms after critical word onset, based on Federmeier, Mai & Kutas (2005). Data were exported to SPSS 20.0 for the statistical analyses.

Repeated measures ANOVAs were used to analyze the individual electrodes and the grand mean (average of the separate electrodes) with cloze probability (high versus low) as within-subject factor and manipulation condition (control versus reward prospect) as between-subject factor. Furthermore, paired samples T-tests were used to clarify the distribution pattern of excitation among electrodes, a simple T-test was used to compare the test results between the conditions and a Pearson's correlation analysis was done to compare the test results to the intensity of the N400-response.

Lastly, the data was checked for violations of assumptions. First, the data was analyzed for multivariate outliers with the Mahalanobis (1936) analysis. No outliers were found. Then, individual electrode data were checked for normality. No skewness or kurtosis violations were found. Lastly, when sphericity was violated in F-tests from repeated measures ANOVAs, the Greenhouse-Geisser (1959) correction was applied.

Results

Three-Way ANOVA

Repeated measures ANOVA with the cloze effect and electrodes as within-subject factors and manipulation condition (control versus reward prospect) as between-subject factor (Table 1; before split by condition), resulted in a significant general N400-effect, $F(1, 33) = 40.43$, $p <$

.001, η^2 = .55. The large effect size indicates that a strong N400-effect was observed as a result of the reading task in both conditions. This finding is easily visible in the voltage graphs, in which a clear N400-effect is visible for all electrodes in both the manipulation condition (Fig. 1) and the control condition (Fig. 2). Furthermore, a three-way interaction effect with electrodes, condition and cloze proved to be significant, $F(1, 7) = 2.65$, $p = 0.029$, η^2 = .07. This suggested that the distribution of the N400-effect over individual electrodes was somehow different between the two conditions. As a result of this three-way interaction effect, the non-existing interaction effect between condition and N400-response is uncertain. Therefore, conclusions could not yet be drawn concerning the effect of a reward prospect on the N400-response.

Table 1.

ANOVA test for interaction effects between cloze, electrode and condition

Source	*Before split by condition*				*After split by condition*					
					Control			*Manipulation*		
	F	*df*	*p*	*η2*	*F*	*p*	*η2*	*F*	*p*	*η2*
Cloze	*40.43*	*1*	*<.001*	*.55*	*30.79*	*<.001*	*.64*	*12.86*	*.002*	*.45*
Electrode	*18.42*	*7*	*<.001*	*.36*	*13.16*	*<.001*	*.44*	*6.56*	*<.001*	*.29*
*Cloze*Electrode*	*2.83*	*7*	*.008*	*.08*	*5.30*	*<.001*	*.24*	*0.69*	*.659*	*.04*
*Cloze*Condition*	*0.81*	*1*	*.376*	*.02*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
*Electrode*Con.*	*0.97*	*7*	*.453*	*.03*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
*Cloze*Elec.* Con.*	*2.65*	*7*	*.012*	*.07*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*

*Note: Con.: Condition; Elec.: Electrode. Cloze effect is clearly present with high effect size. Three-way interaction effect is significant before split by condition. As Cloze*Electrode shows a significant interaction effect, ANOVA was split by condition. Now, there is a significant interaction effect in the control condition, but not in the manipulation condition.*

Two-Way ANOVAs per Condition

To elucidate the distribution pattern of the N400-effect, individual electrode responses were analyzed for both conditions. First of all, the three way interaction effect between electrodes, cloze and condition was, therefore, split in the two interaction effects between electrodes and cloze in the manipulation and control condition (Table 1; after split by condition). Repeated measures ANOVA revealed a significant interaction effect between cloze and electrode in the control condition, $F(7, 119) = 5.30$, $p = 0.001$, $\eta^2 = .24$. This result indicated that the distribution pattern of the electrode activation in the control condition was irregular. On the contrary, the same analysis for the manipulation condition showed a non-significant interaction between cloze and electrode, $F(7, 112) = .69$, $p = .659$, $\eta^2 = .04$. This finding explains the three-way interaction, as previously found, indicating a difference in electrode activation patterns between both conditions.

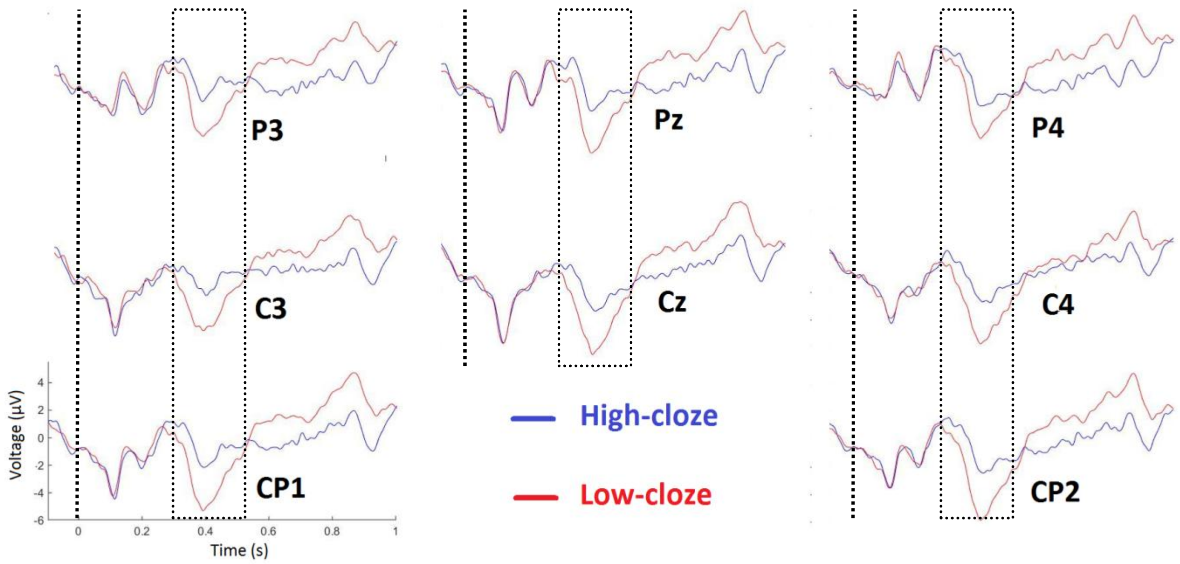

Figure 1. Single electrode responses from 100 ms prestimulus to 1 sec poststimulus from manipulation condition recordings. Dashed line: stimulus onset; dashed rectangle: 300 ms – 500 ms time interval in which the N400-effect is measured. Note that the N400-effect (decrease in voltage after a low-cloze stimulus) is clearly visible in all electrode recordings.

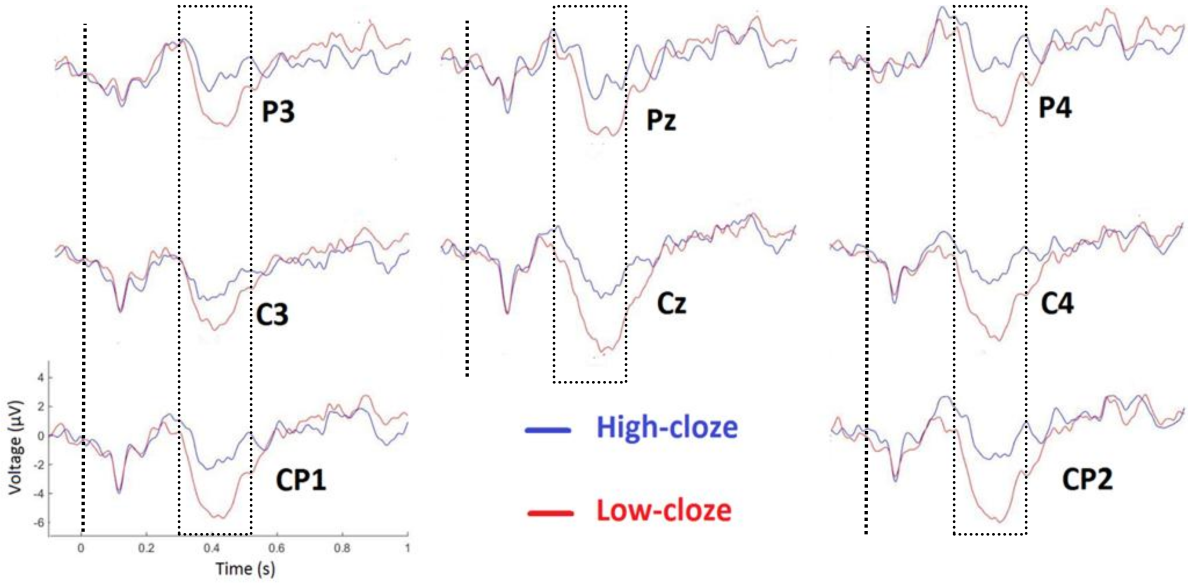

Figure 2. Single electrode responses from 100 ms prestimulus to 1 sec poststimulus from control condition recordings. Dashed line: stimulus onset; dashed rectangle: 300 ms – 500 ms time interval in which the N400-effect is measured. As in the manipulation condition, note the strong N400-effects in these recordings.

Paired Electrode Samples T-tests

For the comparison between the activation patterns in both conditions, paired samples T-tests were performed on single electrode high-cloze/low-cloze pairs (Table 2). Despite the finding that the activation pattern in the control condition was irregular, every single electrode shows a significant response to low-cloze sentences. However, electrode C3 shows a relatively mediocre response with a small effect size in the control condition. In the manipulation condition, a rather similar activation pattern is found, except for a relatively mediocre electrode P4 response. As C3 is located on the left hemisphere, whereas P4 is located on the right, the found inequality between the distribution patterns of electrode activity in the two conditions suggests that a reward prospect shifts the focus of the N400-effect during the reading task towards the left frontal hemisphere (Fig. 3).

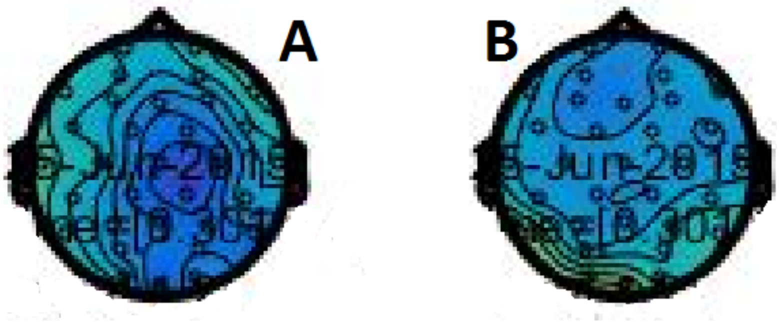

Figure 3. Topoplots of the N400-effect distribution. A: control condition; B: reward prospect condition. A reward prospect induces a shift in activation from the right central cortex to the left frontal cortex.

Rote Learning T-test Between Conditions

Behavioural data was collected in the form of a post-task assessment. In this assessment, as described in the methods, 20 points could be scored. An independent samples T-test revealed that a significant difference in right number of test answers between the manipulation condition (*M* = 10.94, *SD* = 3.31) and control condition (*M* = 8.06, *SD* = 3.32) was found, *t*(35) = 2.58, *p* = .023, *d* = 0.89. So, while neural data show that the intensity of the N400-response in the manipulation condition does not differ from the control condition but the distribution does, this analysis showed the presence of a behavioural effect when it comes to the number of right test answers.

Pearson's Correlation Between N400 and Number of Right Test Answers

Finally, a correlation test was performed between the size of the grand mean N400-effect (mean of N400-effects of all electrodes) and the test scores. This revealed a significant negative correlation, *r*(35) = -.34, *p* = .045. This result implies that an N400-effect reduction is found when rote learning test scores increase.

Table 2.

Paired samples T-tests for electrodes on the N400-effect in control and manipulation condition

Electrode	Control condition					Manipulation condition				
	M	SD	t (17)	p	η2	M	SD	t (16)	p	η2
C3	1.54	2.63	2.48	.024	.27	2.18	2.73	3.30	.005	.40
Cz	3.27	2.48	5.64	< .001	.65	2.24	2.66	3.47	.003	.43
C4	3.20	2.57	5.29	< .001	.62	2.17	3.16	2.83	.012	.33
CP1	2.87	2.77	4.40	< .001	.53	2.29	2.09	4.53	.000	.56
CP2	3.56	2.24	6.72	< .001	.73	2.29	2.32	4.06	.001	.51
P3	2.22	2.00	4.71	< .001	.57	2.02	2.76	3.02	.008	.36
Pz	2.74	2.36	4.93	< .001	.59	2.18	2.86	3.14	.006	.38
P4	3.02	2.20	5.82	< .001	.67	1.50	2.97	2.07	.055	.21

Note: M: mean difference score between high-cloze and low-cloze N400-response; SD: standard deviation; t value: paired-samples T-test; η2: effect size. Means and effect sizes are insignificantly lower in the manipulation condition. Electrodes C3 in the control condition and P4 in the manipulation condition show deviating N400-effects.

Discussion

Semantic processing is regarded as one of the brain's ways to give meaning to incoming stimuli. Therefore, the N400-ERP has the potential to play a role in unravelling the learning process. The purpose of this study was to expand our knowledge about the use of rewards in learning environments, by (a) examining whether a reward prospect strengthens the N400-effect in comparison to having no particular prospect and (b) whether an increase in N400-effect relates to an enhancement of rote learning test scores.

Analyses revealed a clear regular N400-effect as a result of the chosen low-cloze and high-cloze sentences. Also, a significant interaction effect between cloze, condition and electrodes was found. Upon further analysis, it was found that not the intensity of the N400-effect itself changed per se, but it was the distribution of the effect that changed. From a slightly right-central focussed signal in the control condition, the reward prospect induced a shift to a more intense left frontal signal. Lastly and perhaps most surprisingly, it was found that a reduction in N400-effect was correlated with an increase in test score.

This result suggests that the brain partly switches to a qualitatively different cognitive strategy in favour over maximal semantic processing, because of the reward prospect. Although it is hard to identify the underlying process or strategy that has been used, it is likely to expect that a form of processing was chosen that better suited the rote learning task that was appointed at the cost of deep understanding of the presented material. As the frontal cortex is known to be involved in short-term memory formation (Buckner, Kelley & Petersen, 1999), it could be that this cognitive strategy was used more dominantly in the reward prospect condition, explaining the qualitative shift in the distribution pattern of N400-ERP responses.

Implications for Classroom Practice

Despite the fact that teachers do not bribe their students by awarding money for better test results, our grading system itself can be regarded as a behaviouristic tool with an intrinsic reward and punishment feature (Ormrod, 2008). This study adds to the debate on the functionality and disfunctionality of this grading system to aid optimal learning at schools (Schneider & Hutt, 2014). Although the test that was administered in this study demanded rote learning during the reading task, the N400-ERP was measured as a means to quantify deep, semantical processing and the process of giving meaning to the presented stimuli. This setup is highly comparable to a large deal of formal schooling, in which content is presented during lessons and students are expected to truly and deeply understand it, while the test itself mainly measures the attained knowledge by means of rote learning (Mayer, 2002). Therefore, this study adds critique to rote learning tests, followed by a grade, of material that was meant to be understood thoroughly and deeply. Not because test grades decline, but because of the raised suspicion that the actual learning goal (meaningful learning) is not prioritized by the learner's brain and, therefore, not maximally attained.

This finding is in line with literature on emotion, which suggests that emotional triggers are highly influential in determining the cognitive processing strategy (Fredrickson, 1998). For example, it was found that the state of mood had no impact on the depth of cognitive processing, possibly mediated by attention or motivation, but it did lead to qualitatively different cognitive strategies (Schwarz, 2002). Therefore, we regard it likely that the decrease in effect size of the N400-ERP in the reward prospect condition is caused by (partially) changing the cognitive strategy towards a, for this task, more efficient rote learning one. Despite the possible positive short-term effects on grades, a long-term negative effect is then to be expected because of the lack of meaningful learning (Novak, 2001), resulting in a compromised exit-level of the learner.

Of course, care has to be taken when interpreting neural correlates and drawing causal relations with the complex, real-life classrooms. Some levels of scale exist between these two, necessitating highly cautious handling of the information (Willingham, 2009). Moreover, this study was initially designed to investigate the opposite hypothesis, which means that more targeted studies are necessary to further elucidate the findings presented in this study. Nevertheless, this study opens the path to fuelling educational discussions about the use of behaviouristic tactics with knowledge from the learner's brains. In addition, these results provide food for thought for the critical and curious teacher to analyze their own work or even to aid scientists in developing crucial experiments and insights (Goswami & Szúcs, 2011).

Implications for Further Research

Although it was not measured in this study, responses of participants struck us in a sense that participants described their memorization strategies more often and more elaborate in the reward prospect condition. These were often in the form of chunking or relating concepts or names to images or memories, reflecting bottom-up cognitive strategies (Gobet et al., 2001). Previous research has shown that mood induction was effective in influencing whether the participant made use of a top-down cognitive processing strategy, or a bottom-up style (Chwilla, 2011). Perhaps some similar mechanism has occurred in this study, where the reward prospect stimulated the participants to use bottom-up processing strategies, aimed at remembering instead of comprehending. More research on these strategies might reveal whether conscious cognitive strategies accounted for our findings.

One can argue whether or not the set-up in this study was ecologically valid, in relation to real-life classrooms. First of all, the reading task is quite dull and passive, in comparison to regular, more interactive and active lessons. Secondly, especially in the control condition, the test had no value for the participant, other than the obligation to complete it. Thirdly, low-cloze sentences do not occur during regular learning tasks, as they are meaningless. Lastly, it is uncertain whether a monetary reward prospect elicits a behaviouristic correlate for classroom practice. It must be noted that EEG-study designs bring along inherent ecological difficulties and social interactions are necessarily neglected (Hutzler et al., 2007). Despite these methodological challenges, we believe that the set-up in this study was sufficient to allow for primary investigation of the effect of a reward prospect on semantic cognitive processing. Based on the findings in this study, more specific and ecologically valid studies can originate, elucidating the cognitive processing strategies of students during different types of learning. In addition, it would be interesting to gain a better understanding of the neural behaviour of these cognitive processing strategies when comparing a learning task that will be summatively assessed versus a task that will be formatively assessed.

Methodological Uncertainties

A difficult issue is that our knowledge on the exact physiology behind reward and, especially, the expectation of a reward on a prospective memory task is yet developing (Gäbel, 2010). That means that literature on reward prospects has not clearly clarified how to trigger this emotion and how grades and tests are related to the physiology of the brain's reward system-. Moreover, we lack knowledge on how reward and reward prospect influence cognitive processing strategies or other parts of the brain in general, although it is clear that it does (Kawagoe, Takikawa & Hikosaka, 1998). Furthermore, theories arise that reward is not perceived absolutely. Instead, expectation about the upcoming reward's strength, relative to the acquired reward, determines the actual feeling of reward (Glimcher, 2011). Moreover, individuals can use different cognitive strategies to regulate their reward expectation (Delgado, Gillis & Phelps, 2008). As the expectation of the received reward likely differs between participants, possibly based on their previous experiences, it is unsure whether or not the same reward prospect induction procedure elicits equal cognitive strategy responses between participants. It would be interesting, in light of individual neural reward system differences in the classroom, to gain more insight in the strength of this confounding effect on cognitive strategies in general.

Secondly, N400-ERP has even been shown to occur in response to incongruences in the absence of deliberate attention (Deacon & Shelley-Tremblay, 2000). Therefore, attention and motivation to perform on the task are not absolutely necessary for an N400-response. However, meaningful learning is never thought to arise without conscious and attentive effort (Shuell, 1990). Therefore, as one of the most critical discussions when considering the practical implications of the N400-ERP studies, it would be interesting to study to what extent meaningful learning relies on the N400-response.

Conclusion

This study was designed to measure the N400-ERP response during a reading task when a reward prospect was present. Unexpectedly, we found no quantitative, but a qualitative shift in distribution of N400-ERP responses as a result of the reward prospect. Furthermore, the rote learning test that was administered, showed a marked increase, negatively correlating with the N400-ERP. This finding suggests that, in line with previous studies, a qualitative shift in cognitive processing strategies takes place in response to the reward prospect. Although this provides short-term benefits, caution must be paid to the loss of deep understanding that could lead to a long-term learning disadvantage. As this study tries to connect neural correlates to classroom behaviour, there are still many methodological and ecological problems to overcome before final arguments can be made about classroom practice. Until then, these results serve to inspire new research and to provide critical and curious teachers with food for thought.

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