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Pictorial vs. linguistic negation: Investigating negation in imperatives across different symbol domains

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ABSTRACT

The processing of negation is typically regarded as one of the most demanding cognitive processes as it often involves the reversal of input information. As negation is also regarded as a core linguistic process, to date, investigations of negation have typically been linguistic in nature. However, negation is a standard operator also within non-linguistic domains. For example, traffic signs often use negation to indicate a prohibition of specific actions (e.g., no left turn). In the current study, we investigate whether processing difficulties that are typically reported within the linguistic domain generalize to pictorial negation. Across two experiments, linguistic negation and pictorial negation were directly compared to their affirmative counterparts. In line with the literature, the results show that there is a general processing benefit for pictorial input. Most interestingly, the core process of negation also benefits from the pictorial input. Specifically, the processing difficulty in pictorial negation compared to affirmation is less pronounced than within the linguistic domain, especially concerning error rates. In the current experiments, pictorial negation did not result in increased error rates compared to the affirmative condition. Overall, the current results suggest that negation in pictorial conditions also results in a slowing of information processing. However, the use of pictorial negation can ease processing difficulty over linguistic negation.

1. Introduction

A picture is worth a thousand words – a famous saying summarises a core psychological phenomenon, the picture superiority effect (Koenke & Otto, 1969; Paivio, 1971; Paivio et al., 1968; Shepard, 1967). In many studies it has been shown that recall and memory for pictures is significantly better than for words. Also, in real life, pictorial displays are often regarded as more efficient compared to verbal displays, for example, in the context of traffic signs (e.g. Bartłomiejczyk, 2013; Jacobs et al., 1975). Less clear to date is in how far pictures help specific types of mental processes beyond general memory or identification benefits. In the present study, we investigate how far negation – typically regarded as a core linguistic process – is similarly processed for different symbolic modalities. Specifically, we aim to investigate processing differences in linguistic and pictorial negation and analyse whether processing problems for negation integration differ between input modalities.

Negation is known to be an extremely complex and cognitively demanding process, often involving an internal reversal process (e.g., Beltrán, Muñetón-Ayala, & de Vega, 2018; Dudschig & Kaup, 2018; Kaup & Dudschig, 2020; Palaz et al., 2020; Wirth et al., 2019). When applied to a statement with truth conditions, negation usually results in the reversal of their truth value: If a statement such as “*The dress is new*” is true, its negative counterpart “*The dress is not new*” is false and vice versa (for exceptions such as expletive negation, see Horn, 1989; Delfitto & Fiorin, 2014). However, negation can also be applied to linguistic structures without truth conditions, such as questions, prayers, commands etc. (see Horn, 1989 for a thorough discussion). In this case, negation also often calls for internal reversal processes. For instance, in a situation in which only two responses are possible, such as turning left or right at a T-junction, the command “not left!” from a fellow passenger is equivalent to the instruction to turn right, and “not right!” is equivalent to the instruction to turn left. Negation processing is typically reported to result in behavioural slowing and more error-prone behaviour (e.g., Deutsch et al., 2006; Deutsch et al., 2009; Dudschig et al., 2018; Dudschig & Kaup, 2018). Such ironic effects of negation are reported across a wide range of studies, suggesting that using negation (e.g. “*Make sure you do not cross this line when doing this task*”) often results in exactly

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those type of behaviours that should be avoided (e.g., Wegner, 1994; Wegner et al., 1998). These effects are also reported in everyday behaviour such as eating habits and the influence of negation on changing these habits (Adriaanse et al., 2011). Specifically, implementation intentions containing negation (e.g., "*if I am sad, then I will not eat chocolate*") resulted in ironic rebound effects (i.e. increased chocolate intake), compared to control conditions. Also, when having to reverse previously learned rules via choosing or being instructed to not follow the rule and inverse the instruction (e.g. learned rule: if you see x move your finger to the left top button - > inverse - > finger needs to be moved to top right button; Pfister et al., 2016; Wirth et al., 2016), it can be observed that in so-called 'rule violations trials' participants have a strong bias towards rule-compliant motor actions which can be observed in finger movement trajectories. Thus, in language processing, the use of a negation operator – despite being a crucial part of every language (see Horn, 1989) – typically results in increased processing times and error rates. Only in situations where negation occurs in a pragmatically licensed context (e.g., "*With proper equipment scuba diving isn't dangerous*", Nieuwland & Kuperberg, 2008), does negation processing seem rather easy (see also Nieuwland, 2016).

Are there any other parameters that help with negation processing? Various studies addressed the question of whether with extensive practice negation integration becomes automatic. For example, Deutsch et al. (2006) showed across various experiments that negation processing is hard to facilitate by practice. In particular, it seems impossible to transfer from previous negation practice to negating new information. In a recent study, Dudschig and Kaup (2018) showed that negating spatial directional words (e.g. "not left" vs. "now left") results in a reaction slowdown of approximately 150 ms and even after extensive practice of repeating negation instances, the negation effect persists. Also, additional time to prepare for the upcoming negation process does not resolve the processing difficulty (Dudschig et al., 2019; Dudschig, Kaup, 2020a). Overall, one can summarise that negation is a challenging cognitive process, and there are only a few parameters identified that ease negation integration. Despite the considerable effort that is required for negation processing, being able to negate information is a crucial aspect of human cognition in various domains.

Negation is often regarded as a linguistic process. However, as mentioned above, negation is a general phenomenon that is of core interest within research on thinking, reasoning, logic, stereotype formation, emotion control, but also in more applied contexts of psychology for example when processing traffic signs (e.g., Ells & Dewar, 1979; Gawronski et al., 2008; Herbert et al., 2011; Herbert et al., 2012). Interestingly, negation nevertheless has predominantly been investigated within the linguistic input domain. A few studies have focused on negation effects within non-linguistic domains, specifically the pictorial domain. First, Giora et al. (2009) investigated pictorial negation across a wide set of stimuli. Specifically, this study targeted to investigate whether pictorial negation involves similar processes as linguistic negation – specifically with regard to maintaining the to-be-negated information in memory. Indeed, the authors showed via a rating study that similarly to linguistic negation, pictorial negation also results in the information to-be-negated to remain highly accessible for participants. Second, Walker et al. (1965) investigated the processing of linguistic versus pictorial road signs. In particular, they used the phrases "no right turn", "no left turn" and "do not enter" and compared them to their visual counterparts (see Fig. 1). They used a tachistoscopic stimulus presentation, and participants had to write down which stimulus they had perceived. Afterwards, the authors analyzed accuracy measures. The key finding shows that participants are more accurate in writing down what they had seen in the picture condition compared to the linguistic condition. After a 24 h delay, the pictorial stimuli were recalled with 100% accuracy. The authors conclude that there is a crucial processing benefit of pictorially conveyed information over the identical information conveyed in a linguistic form. However, the authors point out certain limitations. For example, the pictorial information was more visually integrated, whereas the linguistic input was more segmented. Additionally, as this study was not specifically interested in negation processing – but rather in general processing differences between pictorial and verbal traffic signs - it remains open whether the observed advantage is a general processing advantage for pictorial information, or whether the negation process itself is facilitated for a pictorial format.

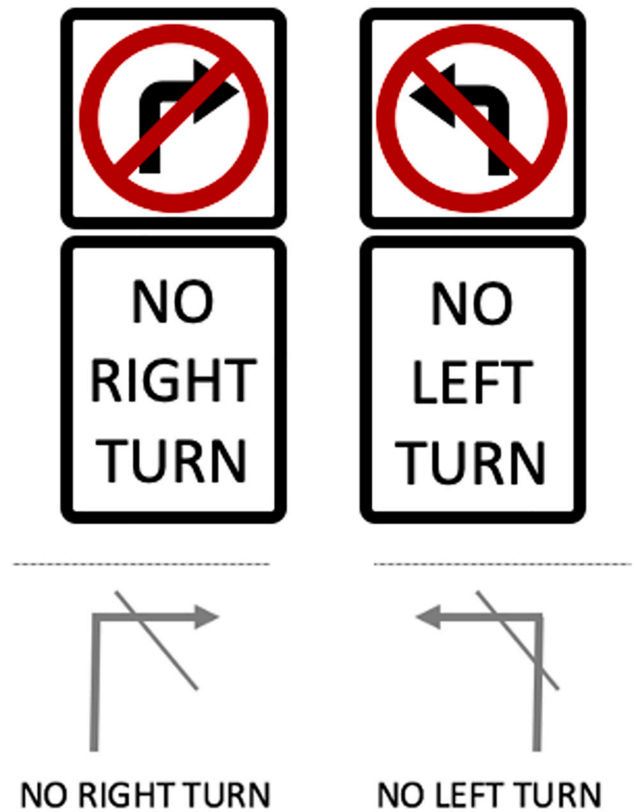

Fig. 1. Top plot: example of traffic signs as used across many countries. Bottom plot: stimuli used by Walker et al. (1965).

Other studies investigating the processing of verbal versus pictorial traffic sign information also focused on processing modality across a wide range of different types of information conveyed by traffic signs (e.g., hills, bumps, left turns). In this context, Ells and Dewar (1979) showed that verbal traffic signs are usually slower to identify than pictorial traffic signs, which might be a consequence of pictorial traffic signs being more prevalent in our daily experience than their verbal counterparts. Recently, a debate has addressed the question whether under specific circumstances (e.g., new traffic signs) verbal information or at least the addition of verbal information might be useful (e.g., Shinar & Vogelzang, 2013). Taken together, despite the comparison of verbal and pictorial traffic signs processing being of core interest, the direct influence of input format on the negating process was not yet investigated. Given that pictorial signs implementing a type of negation are often used as standard traffic signs, the current study focused on the question whether these - similarly to verbal negation - are more error-prone than their affirmative counterpart and whether therefore - if possible - should be generally avoided. In contrast, it is possible that the core negation difficulties typically reported in the literature are due to specificities in the linguistic system, and therefore the use of negation is rather unproblematic in pictorial format.

The current study was designed to compare linguistic and pictorial negation directly. Specifically, we investigate the influence of pictorial versus linguistic format on the negation process with regard to speed and correctness of information processing. We aimed to investigate whether negating is a central cognitive process that operates in a similar manner independent of the input format, or whether specific input types ease the core process of negating. We focused our investigation on the processing of imperatives, as in this case the linguistic as well as the pictorial structures do not have truth values and can therefore be directly compared. We used the identical phrases as in previous studies: “not left”, “now left”, “not right” and “now right” (Dudschig & Kaup, 2018) and compared them to their pictorial counterparts. In order to be able to compare pictorial and linguistic input at an integration level, we presented both forms in a disintegrated manner (see details below in the methods section, specifically we present the pictorial information in a sequential format processing from left to right - in line with the standard linguistic presentation format), as linguistic input cannot be integrated without the loss of information (e.g. via displaying words on top of each other) (for discussion on integration see Walker et al., 1965). We also aimed to compare negation to a direct affirmative counterpart to make sure that processing advantages of affirmation do not result from shorter stimulus length - given that in the case of negation an additional negator needs to be processed. Whereas for negation, there are clear pictorial counterparts, for example, crossing something out, the pictorial counterpart of affirmation is less clear (Murray et al., 1998). In the present study, we used the check-mark symbol – although not internationally uniquely used – in English and German-speaking countries it is strongly associated with affirmation, correctness, or more generally the concept of “yes”. It is speculated that the check-mark is derived from using the letter “V” to indicate “yes” or “true”, which is derived from the Latin word “veritas” (= truth) used to indicate approval. It could be argued that the check-mark and the cross represent a sort of linguistic input, with the cross resembling the negation operator in logic. However, these symbols do not have any linguistic morphological shape, diverging from the ones adopted in natural languages across the world - potentially resulting in processing differences between the two symbol domains which will be investigated in the present study.

As negation should be a difficult mental process in general, we expected that negated trials would be slower than affirmative trials across both linguistic and pictorial input (see also Dudschig & Kaup, 2020a). Second, as previous studies suggest that pictorial input is overall easier to process, we expected that pictorial input would result in shorter response times (see Potter & Faulconer, 1975). With regard to the negation process itself, there are two possibilities. On the one side, negation may be a general cognitive process – that is highly cognitively demanding - and does not differentiate between different input modalities. On the other side, it is possible that pictorial input also facilitates the negation process itself. In this case, we expect an interaction between the negation effect and input modality. Two experiments were conducted in order to investigate these hypotheses by measuring reaction time and error rate to both linguistic and pictorial symbols. In Experiment 1, the linguistic and pictorial conditions were presented in a blocked manner. In Experiment 2, the two conditions were randomly intermixed within blocks.

2. Experiment 1

2.1. Method

2.1.1. Participants

Twenty participants took part in this experiment (M_{age} = 25.55, SD_{age} = 4.70, range = 19 to 40, 14 female, 18 right-handed). The sample size was determined using a previous study investigating the negation effect in a similar experimental setup, but using the linguistic negation condition only (Dudschig and Kaup, 2018, 2020b), this resulted in a sample size of 8 participants in order to replicate the negation effect. As we were interested in investigating negation in an additional condition (the pictorial condition), we increased sample size to 20. The data of individual participants were removed from the subsequent analysis if their overall error rate was greater than a predefined error rate of 20%. This resulted in the exclusion of one data set. All participants were paid 8€/h or received course credit for their participation. All participants signed informed consent.

2.1.2. Stimuli and procedure

The experiment was programmed in Matlab (2017a) running under Ubuntu 18.04 using Psychtoolbox (3.0.14) extensions (Brainard, 1997; Kleiner et al., 2007; Pelli, 1997). Stimuli were presented on a 17 in. CRT monitor (1152*864, 100 Hz). The stimuli were all displayed in black (RGB 0,0,0) on a white (RGB 255,255,255) background in the centre of the screen. Each trial started with the presentation of a 750 ms fixation cross (size: 0.5 cm × 0.5 cm) (see Fig. 2 for trial procedure). This was followed by the presentation of either a linguistic or pictorial response stimulus. The linguistic response stimuli were the four phrases “jetzt links” (“now left”), “nicht links” (“not left”), “jetzt rechts” (“now right”) and “nicht rechts” (“not right”) (size approximately 2.4 cm × 0.7 cm). The pictorial stimuli were constructed as follows: the unicode symbols (check mark (✔) with decimal code: &#10,004; ballot x (✗) with decimal code &#10,007; leftwards arrow (←) with decimal code: ← rightwards arrow (➔) with decimal code: &#8594). The stimuli were always displayed until response or a maximum of 2000 ms. If no response occurred within 2000 ms the feedback “Zu Langsam” (“Too Slow”) was displayed for 1000 ms. Responses executed within 150 ms were defined as “anticipations” and were presented with the feedback “Zu Schnell” (“Too Fast”). The feedback “Falsch” (“Incorrect”) was presented to erroneous responses. Participants responded using their left and right index fingers with an external response box. The left and right response buttons were positioned approximately 15 cm apart in the horizontal plane. The experiment consisted of 10 blocks, whereby two were practice blocks. The manipulation of linguistic versus pictorial symbols was conducted across blocks. Half of the participants started with the linguistic condition and the other half started with the pictorial condition. Block 1 always was a practice block of 16 trials followed by four experimental blocks (each 96 trials) using the same symbol type. Block 6 again was a practice block of 16 trials now introducing the other symbol type, followed by four experimental blocks.

2.1.3. Design

The design was a 2*(polarity: affirmative vs. negated) * 2 (symbol type: linguistic vs. pictorial) repeated measure design. The dependent variables were reaction time and error rates.

2.2. Results

The overall error rate was 8.46% (5.55% following the removal of one participant's data). Individual trials classified as too fast (<150 ms) or too slow (>1500 ms) were removed from the subsequent reaction time analysis, resulting in the removal of 1.38% outliers. The mean RTs and error rates are displayed in Fig. 3. The reaction time analysis showed a main effect of polarity, $F(1, 18) = 169.68$, $p < .001$, $\eta^2_p = 0.90$ (M_{aff} = 662 ms, M_{neg} = 761 ms). There was also a main effect of symbol type with faster response times in the pictorial compared to the linguistic condition, $F(1,18) = 28.08$, $p < .001$, $\eta^2_p = 0.61$ (M_{lang} = 773 ms, M_{pic} = 650 ms). Finally, there was an interaction between polarity and symbol type, $F(1,18) = 68.78$, $p < .001$, $\eta^2_p = 0.79$, due to the negation effect being smaller in the pictorial condition. Post-hoc *t*-test comparisons showed that both in the linguistic ($t(18) = 15.38$, $p < .001$, $d = 3.53$) and the pictorial condition ($t(18) = 4.82$, $p < .001$, $d = 1.11$), the negation

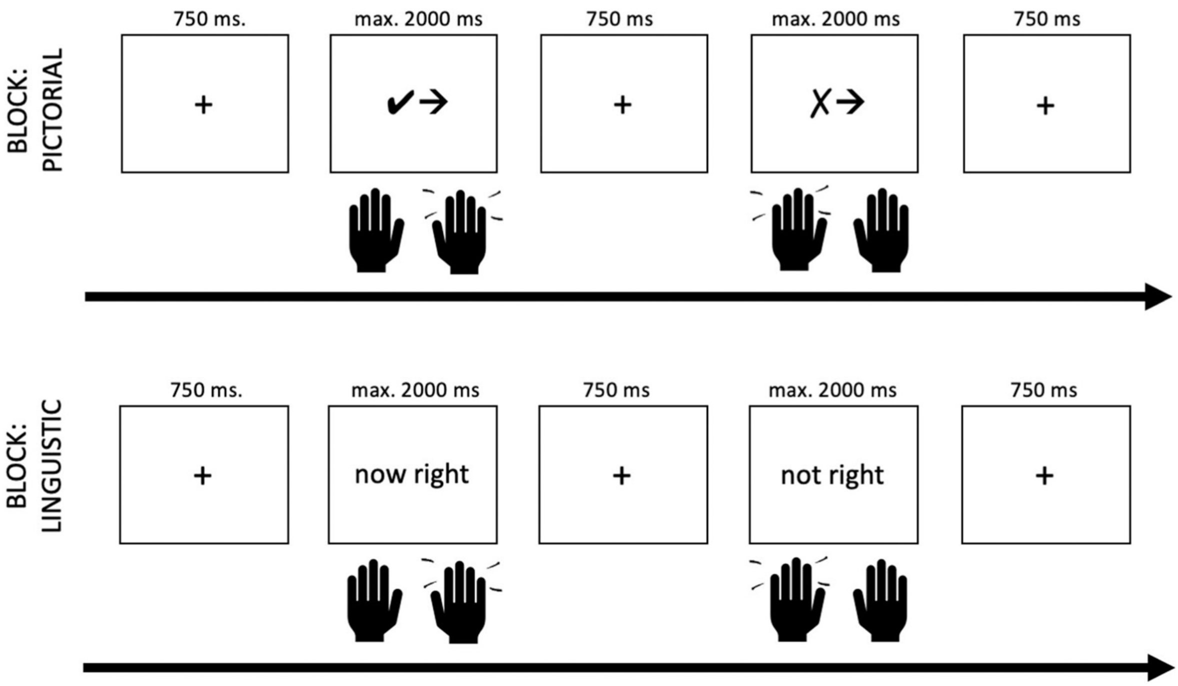

Fig. 2. Trial procedure (top: pictorial blocks; bottom: linguistic blocks).

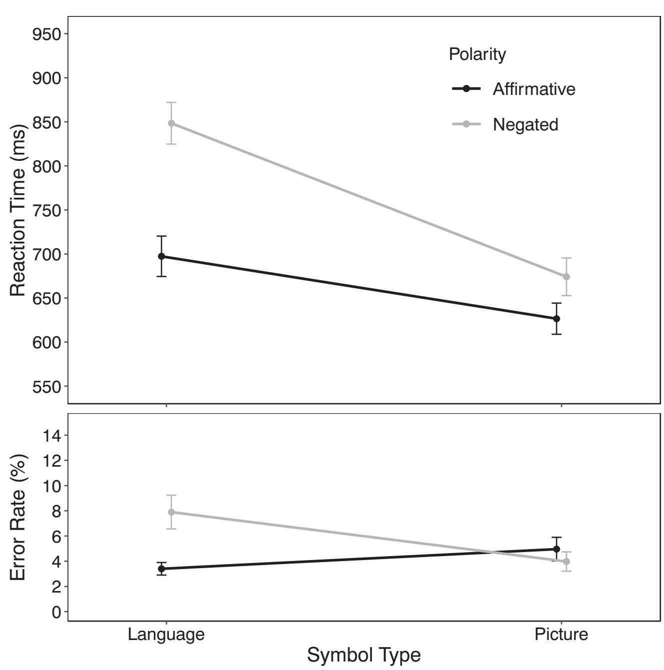

Fig. 3. Reaction time (top) and error rate (bottom) as a function of polarity (affirmative vs. negated) and stimulus type (linguistic vs. pictorial). The errorbars represent ±1 *SEM*.

effect was significant. The error rates analysis showed similar effects. There was a main effect of polarity, $F(1, 18) = 7.12$, $p < .02$, $\eta^2_p = 0.28$ ($M_{aff} = 4.18\%$, $M_{neg} = 5.93\%$), and a main effect of symbol type, $F(1, 18) = 7.23$, $p < .01$, $\eta^2_p = 0.29$ ($M_{lang} = 5.65\%$, $M_{pic} = 4.47\%$), as well as an interaction between negation and symbol type, $F(1, 18) = 14.39$, $p < .01$, $\eta^2_p = 0.44$,[1] due to the negation effect being larger in the linguistic condition. Post-hoc *t*-tests showed a significant negation effect in the linguistic condition ($t(18) = 4.06$, $p < .001$, $d = 0.93$) but not in the pictorial condition ($t(18) = 1.19$, $p = .25$, $d = 0.27$).

3. Experiment 2

Experiment 2 was conducted to replicate the findings from Experiment 1 in a slightly different experimental setup. This time, the linguistic and pictorial conditions were randomly intermixed instead of blocked, in order to prevent any long-time adaptation effects to be responsible for the results in Experiment 1. For example, it would be possible, that learning effects occur in the pictorial but not in the linguistic condition. In order to minimize learning effects by constant stimulus repetition we now intermixed the two symbol formats. Participants completed a practice block of 16 trials followed by 9 blocks of 96 trials.

3.1. Method

3.1.1. Participants

Twenty-five participants took part in this experiment ($M_{age} = 23.60$, $SD_{age} = 3.19$, range = 19 to 30, 17 female, 23 right handed). The sample size was increased to 25 as we anticipated a higher exlusion rate based on the participants' error rates, as we assumed the within manipulation to be more error prone. As in Experiment 1 the data of individual

[1] An additional analysis was conducted. Specifically, the negation effect was analyzed as percentage of the mean RTs separately in the language and the pictorial condition for each participant. Despite this normalizing procedure in order to take into account the main difference between condition, there was still a significant difference in the size of the negation effect between the two symbol types, suggesting that the larger negation effect was not just proportional to the overall slower RTs in the language condition.

participants were removed from the subsequent analysis if their overall error rate was greater than a pre-defined error rate of 20%. In line with Experiment 1 – and contrary to our expectations - this resulted in the exclusion of one data set. Participants either received 8€/h or course credit for their participation. All participants signed informed consent.

3.1.2. *Stimuli and procedure*

Identical to Experiment 1 with the only difference that the linguistic and pictorial condition were randomly intermixed.

3.1.3. *Design*

The experimental design was identical to Experiment 1.

3.2. *Results*

The overall error rate was 7.38% (6.55% following the removal of one participant). Individual trials classified as too fast (<150 ms) or too slow (>1500 ms) were removed from the subsequent reaction time analysis. This resulted in the exclusion of 1.37% of the trials. The mean RTs and error rates are displayed in Fig. 4. The results of the RT analysis showed a main effect of polarity, $F(1,23) = 326.27$, $p < .001$, $\eta^2_p = 0.93$ ($M_{aff} = 629$ ms, $M_{neg} = 736$ ms). Again there was a main effect of symbol type with faster response times in the pictorial condition, $F(1, 23) = 36.12$, $p < .001$, $\eta^2_p = 0.61$ ($M_{lang} = 737$ ms, $M_{pic} = 628$ ms). The interaction between negation and symbol type again was significant, $F(1, 23) = 39.18$, $p < .001$, $\eta^2_p = 0.63$, indicating that the negation effect again was smaller in the pictorial condition. Post-hoc *t*-test showed that for both the linguistic ($t(23) = 17.67$, $p < .001$, $d = 3.61$) and the pictorial condition ($t(23) = 7.61$, $p < .001$, $d = 1.55$) the negation effect was present. For the error rate analysis, there was a main effect of polarity, $F(1, 23) = 22.83$, $p < .001$, $\eta^2_p = 0.50$ ($M_{aff} = 4.72\%$ ms, $M_{neg} = 7.43\%$), no main effect of symbol type, $F(1, 23) = 1.64$, $p = .21$, $\eta^2_p = 0.07$, but an interaction between polarity and symbol type, $F(1, 23) = 15.55$, $p < .001$, $\eta^2_p = 0.40$. Post-hoc *t*-tests showed that the negation effect was present in the linguistic ($t(23) = 7.01$, $p < .001$, $d = 1.43$) but not in the pictorial condition ($t(23) = 0.51$, $p = .62$, $d = 0.10$).

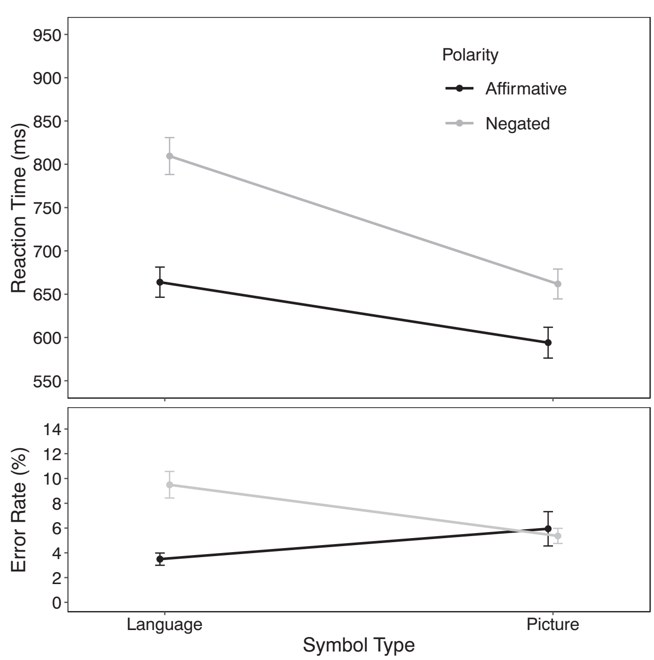

Fig. 4. Reaction time (top) and error rate (bottom) of Experiment 2 as a function of polarity (affirmative vs. negated) and symbol type (linguistic vs. pictorial). The errorbars represent ±1 *SEM*.

4. Discussion

The present study was designed to investigate negation processing across different symbol domains. Despite negation being typically regarded as a core linguistic process, negation processing plays a role in various other domains (e.g., emotion control, eating control, visual processing). Here we focused on the direct comparison of negation in the linguistic and the pictorial input domain. Negation typically results in increased processing efforts and therefore leads to reaction time slow-downs when compared to affirmative conditions. Nevertheless, in everyday life negation is used frequently both in linguistic and visual contexts (e.g. displays in traffic signs). Previous studies showed that memory effects are better for visual input compared to linguistic input of negation, however, no direct comparison on the processing times has yet been conducted (Walker et al., 1965). In the current experiments focusing on the processing of commands, the reaction time results show a slow-down in both the linguistic and the pictorial negation condition. Crucially, this slow-down is particularly pronounced for the linguistic input domain and significantly reduced for the visual input domain. Interestingly, the error data was even more input specific: In the linguistic condition there was an increase in errors in the negation condition, however, this increase was not observed in the pictorial input condition. Therefore, the present study suggests that the use of negation in commands in the pictorial context seems less problematic than the use of negation in the linguistic contexts.

There are several interesting issues that need to be discussed with regard to the present findings. Overall the current results show that negation processing is facilitated for the pictorial modality compared to linguistic modality. Nevertheless, there is still a significant processing cost in the negated compared to the affirmative pictorial condition. Therefore, it remains open whether pictorially displayed negation could be eased to a processing level that is as easy as affirmation. Indeed, in the linguistic domain, there are conditions were licensing contexts facilitate negation processing up to such a level (e.g., Nieuwland & Kuperberg, 2008). Nieuwland et al. argued that negation is such a common phenomenon in language use that is seems unlikely that it always results in increased processing costs. Therefore, they investigated negation in contexts where negation seems more natural – and therefore pragmatically licensed – showing that negation processing can be highly eased (see also Greco et al., 2020; Orenes et al., 2014; Orenes et al., 2016). This might also be possible in visual contexts, for example, in the case of traffic signs. Here, it might be possible that under certain contexts negated directional symbols are easier to process than their affirmative counterparts. Future studies are needed to fully understand under which conditions pictorial negation processing might be fully licensed. Alternatively, however, pragmatic licensing might also mainly play a role in the linguistic domain. If so, this would offer one possible explanation for the increased difficulty of negation processing in the linguistic domain in our study. We presented negation without a licensing context in both the linguistic and the pictorial trails, and maybe this has increased negation processing difficulty particularly in the linguistic condition. However, it should be noted that as far as we know the relevance of pragmatic licensing contexts for negation processing has not yet been investigated for commands.

Given that negation results in reduced processing impairments if implemented in the pictorial condition, this points towards specificities in the linguistic system being responsible for some of the effects reported regarding negation processing. For example, the ironic effects of negation are typically reported when using negation for instructing participants to fulfil a specific task. Error rates are specifically relevant with regard to ironic effects of negation (Wegner et al., 1998). Specifically, ironic effects of negation refer to the fact that specific errors are particularly likely to occur if an instruction puts special focus on avoiding these specific types of errors via negation (Wegner et al., 1998). For example, Wegner et al. reported that during a golf putting game or a pendulum swinging game, errors were more likely to occur if they should be specifically avoided via an instruction using negation (e.g., "do not overshoot" -> overshooting) than when it was not instructed to avoid this exact type of behaviour. Interestingly, the pictorial condition did not result in increased error rates suggesting that pictorial negation is easier to process than linguistic negation (Jentzsch & Dudschig, 2009; Meyer, Irwin, Osman, & Kounois, 1988; Schouten & Bekker, 1967). Given our result that pictorial negation is less error-prone than verbal negation, this speaks in favour of increased processing ease regarding pictorial negation use in everyday life.

Potentially, the current study underestimates the benefits of pictorial display on negation processing. Why is this the case? In the current study, we chose a non-integrated way of pictorial negations. We did this as we aimed to keep the input information as similarly as possible between the pictorial and the linguistic condition. However, in real life traffic symbols the pictorial signs are often integrated, and therefore might be even easier to process than in the current study. Thus, as pictorial negation was easier to process than linguistic negation in our study despite the non-integrated presentation format, we can conclude that pictorial displays should be preferred when instructing such rather complicated cognitive processes involving reversal processes.

Critically, in the current experiments, we changed not only the input format of the negation/affirmation operator but also the input format of the to-be-negated information (left/right vs. arrow). Therefore, the question arises in how far the format change of the directional cue influenced the present results. It is rather clear that the general speed-up of responses in the visual condition might result from the use of pictorial information not only for the negator but also for the directional cue. However, this speed-up should be present in both the affirmative and negation conditions to a similar level. This is reflected in the main effect of input format. In contrast, the interaction between input format and negation is difficult to be explained by the use of arrows versus directional words. This effect is likely due to the input format of the negator also playing a role in the speed with which the negation is processed. For future studies, it might be interesting to combine pictorial negator information with linguistic directional cues in order to disentangle the interplay between these formats further. However, as such combinations are less natural compared to fully linguistic or fully pictorial input format, we do not think that these combinations would be a key to answering the core question addressed in the current paper.

In summary, our results point towards the idea that pictorial information is not only superior to linguistically presented information with regard to memory effects (see e.g. Walker et al., 1965) but also when processing demanding negation operations. Thus, negation still results in slow-downs if presented pictorially, but these are significantly less performance impaired than if presented linguistically. Thus, if it cannot be avoided to use negation in an instruction, ideally a pictorial format should be used.

CRediT authorship contribution statement

Carolin Dudschig: Conceptualization; Methodology; Formal Analysis; Writing – Original Draft; Writing – Review; Funding acquisition.
Barbara Kaup: Resources; Writing – Review.

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