Self-generated and Cue-induced Expectations: Differences and Interactions

DISSERTATION

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Abstract

Expectations help to guide human behavior. Expectations play an important role in psychological theories about both proactive action control (Kunde, 2006) and reactive actions. For example, responses to expected events/stimuli are faster and less error prone than to unexpected events. In spite of this role in different psychological theories and corresponding experiments the operationalization of expectations is heterogeneous (which can lead to contradictory results) and very often conducted indirectly via cues. In 1982 Acosta showed that cue-induced expectations show weaker expectation effects than self-generated expectations, which has since been replicated in different variations, and evidence has been found that this difference is not just quantitative but qualitative (Gaschler, Schwager, Umbach, Frensch, & Schubert, 2014).

The research summarized in this dissertation (three empirical research papers and an opinion paper) dealt with the question how cue-induced and self-generated expectations differ qualitatively, how both types of expectations interact and which operationalization of measuring expectations is more adequate. In the summarized experiments participants had the task to verbalize an expectation and then respond accurately as fast as possible to a presented stimulus which could match or mismatch the expectation. The verbalization could either consist of reading aloud a cue or verbalize a self-generated expectation. In the different studies the features/abstraction of the expectations (and stimuli), the type of response, and the way how the effects of the two types of expectation were measured (within or between trials) were varied.

In a setting that allows a stricter comparison of cue-induced and self-generated expectations (necessitating cue processing) than in previous studies the larger effect of self-generated expectations could be replicated. I confirm and discuss that and how verbalized self-generated expectation effects differ qualitatively from cue-induced effects, i.e. self-generating an expectation puts it in the focus of attention in working memory. On the specific example of conflict expectations, the use of verbalized self-generated expectations can consolidate previous contradictory findings, e.g. about the influence of expectations on the sequential congruency effect. The effects of self-generated and cue-induced expectations are not additive and the effect of a cue is not cancelled if a diverging self-generated expectation is verbalized. In view of these results I critically discuss the operationalization of expectations as cues.

Zusammenfassung

Erwartungen spielen eine zentrale Rolle in der menschlichen Handlungssteuerung. In psychologischen Theorien zur proaktiven Handlungssteuerung (Kunde, 2006) und über reaktive Handlungen sind Erwartungen von besonderer Bedeutung. Sie helfen, sich auf Ereignisse vorzubereiten, auf erwartete Reize kann schneller und präziser reagiert werden als auf unerwartete. Trotz dieser Rolle in verschiedenen psychologischen Theorien und zugehörigen Experimenten, werden Erwartungen unterschiedlich operationalisiert (was zu teilweise widersprüchlichen Ergebnissen führt) und dabei oft nur indirekt über Cues/Hinweisreize gemessen bzw. induziert. Acosta konnte 1982 zeigen, dass cue-induzierte Erwartungen schwächere Effekte hervorrufen als selbst-generierte. Dies konnte seitdem in verschiedenen Variationen bestätigt werden und es gibt Hinweise auf nicht nur quantitative, sondern auch qualitative Unterschiede (Gaschler & Schwager et al., 2014).

Die hier zusammengefasste Forschung (drei empirische Artikel und ein Diskussionsartikel) beschäftigt sich mit der Frage, wie sich selbst-generierte und cue-induzierte Erwartungen qualitativ unterscheiden, wie die beiden Erwartungsformen interagieren und welche Art der Operationalisierung zur Messung von Erwartungen zielführender ist. In den beschriebenen Experimenten hatten Proband_innen die Aufgabe, eine Erwartung zu verbalisieren und dann so schnell und akkurat wie möglich auf einen Stimulus zu reagieren, der diese Erwartung entweder erfüllt (match) oder davon abweicht (mismatch). Die Erwartung konnte dabei entweder durch das Vorlesen eines Hinweisreizes (cue-induziert) oder die Benennung einer selbst-generierten Erwartung verbalisiert werden. Dabei wurden das Abstraktionslevel der Erwartung, die Art der Reaktion und der Vergleich der beiden Erwartungsformen (innerhalb eines Trials vs. zwischen verschiedenen Trials) variiert.

Bei einem Experiment, das einen genaueren Vergleich von cue-induzierten zu selbst-generierten Erwartungen erlaubt (die Cue-Verarbeitung wurde durch das experimentelle Setup stärker forciert), konnte der größere Effekt von selbst-generierten Erwartungen bestätigt werden. Es wird gezeigt und diskutiert, dass und wie sich selbst-generierte Erwartungseffekte qualitativ von cue-induzierten Effekten unterscheiden: Die Selbstgenerierung von Erwartungen bringt das erwartete Ereignis in den Fokus der Aufmerksamkeit im Arbeitsgedächtnis. Am konkreten Beispiel von Konflikterwartungen können verbalisierte selbst-generierte Erwartungen eine zuvor widersprüchliche Forschungslage zum Einfluss von Erwartungen auf sequentielle Konflikteffekte konsolidieren. Die Effekte von selbst-generierten und cue-induzierten Erwartungen sind nicht additiv und der Effekt eines Cues wird nicht durch eine abweichende selbst-generierte Erwartung zunichte gemacht. In Anbetracht dieser Ergebnisse diskutiere ich kritisch die Operationalisierung von Erwartungen als Cues.

Publications

A) Kemper, M., & Gaschler, R. (2017). Self-Generated or Cue-Induced—Different Kinds of Expectations to Be Considered. *Frontiers in Psychology*, *8*.

B) Kemper, M., Gaschler, R., & Schubert, T. (2017). Stronger effects of self-generated than cue-induced expectations when verifying predictions in data graphs. *Journal of Cognitive Psychology*, 1-16.

C) Kemper, M., Gaschler, R., & Schubert, T. (submitted). What should I expect? How self-generated predictions and cue-induced expectations interact.

D) Kemper, M., Gaschler, R., Schwager, S., & Schubert, T. (2016). The benefit of expecting no conflict—Stronger influence of self-generated than cue-induced conflict expectations on Stroop performance. *Acta psychologica*, *163*, 135-141.

1 Introduction

1.1 Literature on Expectations

Expectations play an important role in human behavior, psychological research and theories about human behavior. The vocabulary used for expectations and related/overlapping processes (i.e. anticipation, prediction, prospection and even preparation) are as diverse (Bubic, Von Cramon, & Schubotz, 2010) as the theories describing them.

One theory that unifies perception and action and is widely discussed - not only in psychological literature but that also has an impact on philosophical and machine learning theory - essentially sees the brain as an “hierarchical prediction machine” (Clark, 2013). According to this predictive coding model the brain is constantly trying to minimize prediction errors. In contrast to other models which view perception more as a bottom up process in which sensory information is processed, this model sees perception as a mainly top down process: The brain builds predictions about the input it gets with hierarchical generative models. In this hierarchy higher levels probabilistically predict the activity of lower levels and at each level only prediction errors get processed to the next level in order to adjust the prediction. While it is critically discussed whether this broad model of the brain as a prediction machine holds true in all cases it certainly reflects the importance of expectations for the understanding of human behavior.

Another historic psychological hypothesis - more focused on action (control) - in which expectations play a crucial role is the ideo-motor (IM) hypothesis (James, 1890; for a historic review see Stock & Stock, 2004). Basis of the IM principle is the idea that people form associations between actions and their effects (both very direct, like the sensation of the performed movement, and more extern like the perception of light when the action was to turn on a light switch) and that these associations can be activated in both directions. Deliberate actions are possible because the effects of these actions are anticipated (i.e. expected) and the anticipation of the effects triggers the according action/movement that leads to the effect. Movements are thus represented as their effects (and only as their effects). Early IM theory derived from two historical roots: one that focused on cerebral reflex actions going back to Laycock (1845) and one that focused on intentional behavior going back to Herbart (1816) and Harless (1861). These roots were combined in the IM theory by James (1890). During the first part of the twentieth century the IM theory has played a minor role but has since regained importance in the psychological scientific debate. For example, it is the basis of the Theory of Event Coding (Hommel, 2009; Hommel, Müsseler, Aschersleben, & Prinz, 2001). In this research (previously learned) action effects are often used as stimuli (i.e. cues) prior to the execution of an action. Experimental data is often analyzed in respect to whether action compatible stimuli (stimuli that were previously effects of the respective action) facilitate the according action and action incompatible stimuli (stimuli that were previously not effects of the respective action or even effects of a different/incompatible action) decrease accuracy/speed of the respective action (for example Elsner & Hommel, 2001). These results can give insight into the bi-directionality of the association of actions and their effects. However, in order for goal-directed actions to take place humans do not simply have to respond to typical action effects with the according actions (a rather uncommon scenario outside of psychology labs) but rather actively anticipate/expect these effects before performing the action that then results in the effects. Kunde (2006) discusses the literature concerning this endogenous activation of effect codes through anticipation. He lists a row of experiments that very elegantly investigate the representation format, timing (of choice and initiation of the according movement), number and combination of effects through more or less implicit measurements of the anticipated action effects. However, experiments that explicitly measure expectations (anticipations) about upcoming effects are lacking in the literature about action control.

1.2 Terminology around Expectations, Examples and the Expectation Mismatch Effect

As both the literature around the influence of expectations in human behavior as well as the terminology used for it are diverse I decided to generally use “expectation” in this dissertation. A few exceptions exist, where I discuss literature that specifically uses a different term or name a title which contains a different term. Expectations in the sense of the publications in this dissertation are expectations about (specific features of) a stimulus that will appear within a stimulus-response trial and which the participants then have to respond to. For the included publications I differentiate between “self-generated expectations” and “cue-induced expectations”. The term cue-induced expectation is used when cues are utilized in psychological experiments with the aim to induce expectations even though I discuss (Section 5.3) whether the effects produced by cues are really due to expectations. In other psychological experiments cues are also sometimes used with different aims than to induce expectations, these other forms of cueing are not the focus of the studies included in this thesis.

An example for the influence of stimulus expectations from everyday life would be driving up to a crossroad in a car with the foot above the gas and brake pedals. The decision on which pedal the foot should come down (response) depends on the specific traffic situation (cars coming from other directions or all roads being empty) or whether a traffic light turns green or red (stimulus). When correctly expecting that we have to brake we can put the foot down faster and the risk that we will step on the wrong pedal is lower when the stimulus occurs to which we have to respond with braking. Depending on the circumstances (traffic light coming after a curve and not being visible before turning around said curve or a truck driving in front of us which blocks the view of the rest of the road in front of us) the event we need to respond to might not be visible very far in advance and correctly predicting and preparing for the event (stimulus) is an advantage for responding fast and accurately. We build expectations depending on different factors. Into our expectations we integrate our previous experiences (with traffic, other drivers and traffic lights) as well as external cues: the light turning yellow (a very valid cue), the driver in front of us (slightly) accelerating or decelerating (a cue that is very dependent on the specific driver and thus our experiences with other drivers). While our expectations might sometimes rely entirely on an external cue if this cue is 100% valid and we know that it is (traffic light turning yellow that we see in advance), in everyday situations we usually self-generate expectations integrating previous knowledge about similar situations and probabilities. This phenomenon is reflected in the "probability matching" of stimulus frequencies for expectations found in laboratory experiments.

In a laboratory setting, the complexities of such everyday examples are reduced into trials with specific predefined stimuli and according cues/expectations. Figure 1 shows the temporal sequence for two exemplary trials in a choice-reaction time task with three colors as stimuli. From top to bottom participants first verbalize an expectation (either read aloud a written cue or verbalize their self-generated expectation when the expectation prompt is shown) then a stimulus is shown and then the participants have to respond as fast and as accurately as possible to the respective stimulus (press the button corresponding to the color) in a choice reaction time task (Publication B uses a verification task of the expectation instead). After a short inter trial interval (ITI) the next trial starts with the next expectation prompt. In all publications included in this dissertation the trials with the different types of expectations are sorted block wise, and preceded by practice trials so participants know the procedure of the upcoming trial. Other co-variables or independent variables like stimulus frequency are varied from trial to trial in the different publications. Figure 1 shows both a match (left) and mismatch (right) trial for self-generated expectations (left) and cue-induced expectations (right). Response time (RT) and accuracy of the responses to the stimuli are measured as the dependent variable.

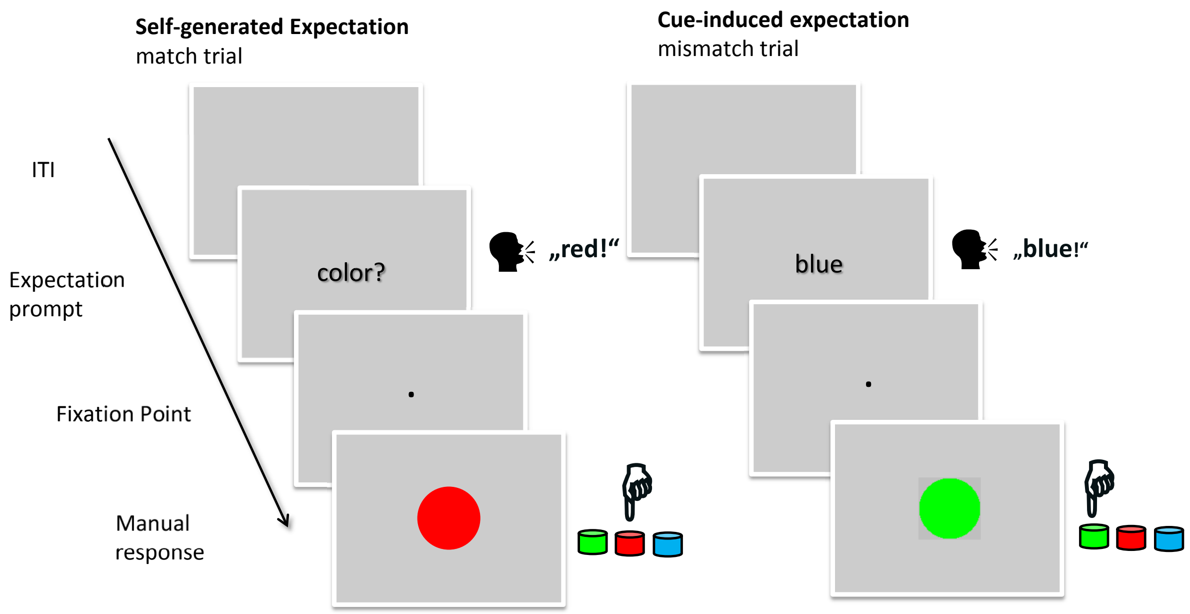

Figure1. Exemplary illustration of two choice-reaction time trials used to compare self-generated to cue-induced stimulus expectations. In this example the stimuli are three colors to which the participants have to respond by pressing the respective button. The left side shows an example from the self-generated expectation condition trial. Here the expectation prompt consists of the question "color?" to which the participant verbalizes the self-generated expectation about the upcoming color. After a short fixation point phase (to ensure the verbalization is finished) the stimulus is shown to which the participant responds by pressing the according button. In this exemplary trial the expectation of the participant is correct - it is a match trial (usually faster responses and lower error rates than mismatch trials). On the right side an exemplary cue trial is shown, here the expectation prompt consists of a written cue the participant reads aloud. In this example the cue does not match the stimulus shown, thus it is a mismatch trial. In all publications in this dissertation both match and mismatch trials have approximately the same frequency in the self-generated expectation condition and in the cue condition.

Expectation effects can be measured in different ways; all publications included in this dissertation use the "mismatch effect". This is a difference effect that is obtained by subtracting the average of the dependent variable (in this case response time) over match trials from the average over mismatch trials. Thus advantage from correct expectations (match trials) and disadvantages from incorrect expectations (mismatch trials) both contribute to the mismatch effect. Note that Acosta (1982) also included neutral expectation trials in his experiments to differentiate these two components of the mismatch effect. When comparing the effect of self-generated to cue-induced expectations, the mismatch effect size for self-generated expectation trials is compared to the mismatch effect size for cue-induced expectation trials, with a larger mismatch effect reflecting a stronger influence of the expectation on the response time (or error rate).

The mismatch effect cannot only be found for behavioral but also for example for Electroencephalography (EEG) parameters (e.g. Jentzsch & Sommer, 2002). The size of the mismatch effect can be influenced by a number of parameters (see Gaschler & Schwager et al., 2014, for a review), among others the overall validity of the expectation. And it can be differentiated from preparation/response time advantages due to other processes than expectation, for example a diverging response time incentive like a penalty for slow responses to one type of stimulus (Umbach, Schwager, Frensch, & Gaschler, 2012). Thus the mismatch effect is an adequate instrument to measure the influence of (different types of) expectations.

1.3 Goals

In the present dissertation I explore the differences between self-generated expectations and cue-induced expectations. I investigate whether the larger quantitative effect (on response time) of self-generated expectations compared to cue-induced expectations found in previous research holds true for different types of expectations (Publications B & D), and how cue-induced and self-generated expectations interact (Publication C). When researching the influence of expectations, it is important that the chosen method really reflects expectations. While the overall larger effects of self-generated expectations suggest that the extensive use of cues to induce expectations in psychological experiments might be worthy of reconsideration (Publication A), looking at diverging expectations within the same trial (Publication C) can give insight into how stable expectation effects are if diverging expectations (of a different format) exist. With regard to these results, this dissertation is meant to aid with the methodological question what format of expectation to use when researching expectation effects. In addition, the studies (especially Publication C) help to gain insight into the (differing) underlying processes of the two types of expectations and how they differ qualitatively.

2 Research Questions and Short Summary of the Methods of Publications A, B, C and D

2.1 Publication A - Self-Generated or Cue-Induced—Different Kinds of Expectations to be Considered

Publication A is an opinion article which gives a short review on the existing literature on cue-induced vs. self-generated expectations (and their effects) in the psychological literature. Following from this short review, I advocate for (also) considering verbalized self-generated expectations as an operationalization for measuring expectations in psychological research in addition to the strong prevalence of cues in the existing literature. In this respect, Publication A is an outlook on this dissertation. While differentiating the effects of self-generated and cue-induced expectations and their underlying processes is one fundamental aspect of this dissertation and the included publications, the other major aspect is the methodological question of how to operationalize expectations in psychological research. I discuss what the existing data imply concerning the usage of cues versus verbalized self-generated expectations when tackling different research questions about expectations. The reviewed studies, as well as the other publications in this thesis, give further insight into considering the trade-off of higher experimental control of cues versus the smaller (and qualitatively different) effects they evoke in comparison to self-generated expectations.

2.2 Publication B - Stronger Effects of Self-Generated than Cue-Induced Expectations when verifying Predictions in Data Graphs

With this study I tried to tackle several topics of my thesis that had not been approached by previous research:

- The usage of more complex/true-to-life stimulus material, which also varied in response irrelevant stimulus features. This should give insight into how expectation effects are influenced by expectations about more true-to-life/relevant stimulus material.
- The usage of different cue formats as well as verbalized vs. non-verbalized cues to investigate whether the differences in effects between self-generated and cue induced expectations are (partially) due to cue format.
- Enforcing a more in-depth expectation processing for all expectation formats by necessitating expectation-stimulus comparisons to fulfill the task. This prevents that cues can be ignored and should thus provide a fairer comparison of cue effects and self-generated expectation effects.

Publication B consisted of two experiments in which participants had to respond to stylized point data graphs that showed either an ascending or descending trend. In three different blocks participants were either verbally cued (the written German words for “ascending” or “descending" were presented), visually cued (with smaller versions of the data graphs used as stimuli) or verbalized their self-generated expectations (again saying the words “ascending” or “descending” to an expectation prompt consisting of a question mark). The task was to compare whether the expectation matched the stimulus (concerning the relevant feature: ascending or descending trend) or not with the press of one of two buttons (match vs. mismatch). All expectations were equally invalid (validity at chance level 50%, with minor coincidental disparities for self-generated expectations, which averaged out over the entire data set). Stimuli as well as visual cues were additionally varied in two visual features: The amount of data points in the graph (3 vs. 5) and the slope angle with which the graph descended or ascended (15° vs. 45° in either direction). In addition to replicating exploratory findings of Experiment 1 in Experiment

2, the two experiments differed in whether the visual cue was additionally verbalized. In Experiment 1 participants said “ascending” or “descending” if they saw the visual cue (small data graph), while they just looked at it in Experiment 2.

2.3 Publication C - What Should I Expect? How Self-Generated Predictions and Cue-Induced Expectations Interact

While all other studies reported in this thesis investigated differences of cue-induced and self-generated expectations by comparing the effects of cues from one set of trials to the effects of self-generated expectations from another set of trials, in this study both expectation formats were measured within the same trials. This experimental setup was used to tackle several research questions that still remained open from the previous research on different types of expectations:

- Whether the two types of expectations are cumulative (show additive or over additive effects).
- Whether one type of expectation dominates the other.
- Whether the underlying process is the same, only activated less strongly or on a fewer amount of trials if cue-induced, or whether the underlying process differs qualitatively.
- Whether different types of (action) modes exist depending on whether the expectation was triggered internally or externally and whether the activation of one mode hampers the other, similar to the effects found in research on action-effect anticipation.
- Whether the previous correctness of the different expectations modulate which respective expectation is relied on. Such a modulation could give insight into

how flexibly different expectation formats can be used and whether participants can switch between relying more on one or the other.

Publication C consisted of one experiment (and a pilot experiment) in which participants had to first verbalize their self-generated expectation about the upcoming stimulus and/or the cue and then respond as fast and correctly as possible to the presented stimulus. The stimulus material used in this experiment consisted of simple shapes similar to those used in previous research on expectations (e.g. Umbach et al., 2012). The three different shapes with three frequencies (10%, 30%, 60%) were mapped to three respective response keys (the relation of specific stimuli to frequencies and response mapping was randomized over participants). The experiment consisted of four different parts (expectation conditions). In addition to one part in which only cues were used and one part in which only self-generated expectations were recorded there were two parts that contained both types of expectations. In one double expectation part of the experiment participants were first asked to verbalize their self-generated expectation and then read a cue before the stimulus was presented. In the other part participants first verbalized the written cue and then their (possibly diverging) self-generated expectation. The validity of all expectations was at chance level (i.e. for cues the frequency of the specific cue was similar to the frequency of the stimulus it cued). The order of the parts was balanced over participants and the temporal order within the trials was manipulated so that the amount of time that passed between the (first) expectation and the stimulus was similar for all parts of the experiment.

2.4 Publication D - the Benefit of Expecting No Conflict - Stronger Influence of Self-Generated than Cue-Induced Conflict Expectations on Stroop Performance

The aim of this study was to investigate the difference of cue-induced vs. self-generated conflict expectations in contrast to the other publications in this thesis which focused on stimulus expectations. In this study expectations were not about the upcoming stimulus itself but about whether the upcoming trial was a conflict trial (incongruent stimulus features) or not. The goal of this study was to see:

- Whether a difference for self-generated and cue-induced expectation effect also exists for conflict expectations (in contrast to stimulus expectations).
- Whether (self-generated) expectations influence the sequential congruency effect. In the context of this thesis specifically whether the utilization of cue-induced vs. verbalized self-generated expectations could give additional insight for the scientific debate about the source of the sequential congruency effect.

The study consisted of an experiment with verbal Stroop task. We used four colors/color words in two pairs to exclude feature repetitions for consecutive trials. 50% of trials were (in)congruent and we manipulated the rows of consecutive (in)congruent trials and congruency level changes similar to Jiménez and Méndez (2013; 2014). Participants had to verbally respond to the stimuli by naming the color the word was written in and (in case of conflict trials) ignore what the word expressed. Before each trial, participants were either cued with a word or verbalized their self-generated expectation concerning the conflict level (congruent vs. incongruent) of the upcoming trial. The German words for “easy” (congruent) and “difficult” (incongruent) were used for both types of expectations (cues and self-generated expectations). Both types of expectations were equally invalid (validity at chance level ~ 50%).

3 Experimental Controls - A Fair Comparison of Cue-Induced and Self-Generated Expectations

When comparing the effects of self-generated expectations to those of cues, the relevant criterion on which the comparison should be based on is the expectation format used in the experimental setup. Confounding variables that differ between the two types of expectations should not be the main contributor to the differences that can be found. In the following section, I discuss some of the possible confounding factors and how I tried to ensure that the difference of effects can be found irrespective of these confounds.

As experimental controls, Study B contained different cue formats and compelled the participants to process cues (and not only self-generated expectations) to fulfill the experimental task. In addition, more true-to life stimuli (and according expectations) were used to control that the type of stimulus was not a contributing factor to the different effects found for cues and self-generated expectations. In Study D, the effects also differed for more abstract expectations (i.e. conflict expectations).

3.1 Cues Also Lead to Smaller Mismatch Effect If Ignoring the Cue Is Not an Option

In Study B I used a verification task instead of a stimulus response task in order to ensure that the cues are processed to complete the task and allow for a fairer comparison to the self-generated expectations. All previous research that had compared self-generated to cue-induced expectations had measured their impact by assessing their influence on behavioral output (see Gaschler & Schwager et al., 2014 for a review) or neurophysiological measures (e.g. Kemper at al., 2012) in stimulus response tasks. Both for stimulus expectations (e.g. Acosta, 1982) as well as for conflict expectations (Publication D) the expectations did influence the performance under certain circumstances but expectations were not explicitly necessary to fulfill the task. While expectations were verbalized (verbalization of self-generated expectations or loud reading of cues) to ensure processing, this might merely lead to shallow processing for the cues that were read aloud (Schooler, Reichle, & Halpern, 2004). The task solely required participants to respond to the stimulus, irrelevant of the previous expectation. Cues might sometimes be ignored, especially if they are of low validity (e.g. Alpay, Goerke, & Stürmer, 2009) while self-generated expectations are not ignored even under such adverse circumstances (Schwager, Gaschler, Rünger, & Frensch, 2016). Also self-generation of expectation has been shown to have strong effects even if the expectation did not refer to which stimulus was expected but rather which stimulus was not expected (Hacker & Hinrichs, 1979) or expected second most (Hacker & Hinrichs, 1974). Thus the previous comparisons of cue-induced to self-generated expectations might not have been entirely equitable. To compensate for this, I used a verification task in Study B. For both experiments participants had to compare their expectations (either cue-induced or self-generated) to the presented stimuli and respond whether the stimulus matches the expectation or not. Thus all expectations were highly task relevant. Nevertheless, my hypothesis was that results would still show a stronger effect of self-generated compared to cue-induced expectations because even with the processing of the cues that was necessary to fulfill the task I proposed that the underlying processes of cue-induced expectations and self-generating expectations differ, with stronger behavioral outcomes of self-generated expectations.

The results I found could replicate previous findings with stronger mismatch effects for self-generated compared to cue-induced expectations in spite of the comparison task used.

In an additional control experiment that was more similar to previous studies on the comparison of self-generated and cue-induced expectations participants had to respond to the stimuli (either pressing a button for “ascending” or for “descending”) instead of comparing the stimulus to the expectation. The results of this control experiment were similar, both to previous studies (stronger effects for self-generated compared to cue-induced expectations) as well as to the main experiments of this study. Thus it was not the task and stimulus material (data graphs) that was responsible for the effects in the main experiment. The same difference of self-generated and cue-induced expectation effects can be found irrespective of whether the task is to respond to the stimulus or verify the expectation. The smaller mismatch effect found for cues cannot simply be explained with the presumption that the cues are ignored (in a larger number of trials) if they are not necessary for the task.

3.2 Expectation Effects for Different Expectation Contents and More True-To-Life Stimuli and Expectations

In order to see whether the stronger effects of self-generated expectations compared to cues were limited to specific expectations/stimuli, expectation content was manipulated and more true-to life stimuli were used.

In Publication D the expectations were more abstract as they did not refer to the upcoming stimulus but the upcoming conflict level. Nevertheless, a mismatch effect could be found for (certain) self-generated expectations but not for cues. This showed that the difference between cue-induced and self-generated expectations is not specifically limited to expectations of concrete stimuli.

In Publication B more true-to-life stimuli and according expectations were used. Data graphs play a steadily increasing role both in scientific research as well as in everyday life and preexisting assumptions (expectations) about data graphs influence how the data graphs are perceived. The influence of expectation on scientific research goes so far that relevant information is overlooked and research results not found if the observer did not have a (correspondent) expectation (Brewer, 2012). Due to this, I considered data graphs a very relevant option for stimulus material when researching expectations. I found an overall mismatch effect as well as a larger mismatch effect for self-generated than cue-induced expectations when using data graphs as stimulus material.

As an exploratory analysis in Publication B I found in Experiment 1 that participants had a tendency to expect ascending graphs more often for self-generated expectations and that this preference for ascending graphs also reflected in overall faster RTs to these stimuli as well as, interestingly, a much larger mismatch effect for ascending stimuli, compared to a minimal (or even reverse for error rates) mismatch effect for descending stimuli. This novel finding could be replicated in Experiment 2 however this effect was similar for all expectation conditions. Thus, while more complex and true-to-life stimulus material can have a strong influence on the overall mismatch effect per se this influence does not seem to cause or alter the difference in the effects of self-generated compared to cue-induced expectations.

As an additional variation of the independent variable, to check which aspect of the cue is responsible for its effect, two different types of cues were used in Publication B: verbal cues (same word as the verbalization of the self-generated expectations) and visual cues (smaller versions of the data graphs used as stimuli). The more complex data graph stimuli differed in more aspects than just the task relevant feature (descending vs. ascending graph) and the visual cues also differed in these features. Neither the difference of stimuli in task irrelevant features overall, nor the according manipulation of visual cues and their congruency to the stimuli in task irrelevant features had an influence on the different mismatch effects of self-generated compared to cue-induced expectations.

While the mismatch effect was of similar size for visual and verbal cues if the visual cues were additionally verbalized (Experiment 1), the effect of visual cues that were only looked at (and not additionally verbalized) was significantly smaller than the effect of verbal cues (Experiment 2), however self-generated expectations always had the largest mismatch effect.

Summed up, for all different types of stimuli and expectations a stronger mismatch effect of self-generated compared to cue-induced expectations could be found.

4 On the Methodology of Operationalizing Expectations in Psychological Research

Since expectations play an important role in action control they are of interest for psychological research. There are several ways to operationalize (the measurement of) expectations when researching the influence of different expectations in psychological experiments. For example, one way would be to tell participants to always expect a certain event for all trials in one block (e.g. Jentzsch & Sommer, 2002) or to implicitly infer expectations from response times: On average the trials with faster response times could be assumed to be those where expectations were more likely to be fulfilled, compared to slower trials where expectations were more likely not to be fulfilled. Yet this is probably not true for every single trial and only helpful if the dependent variable the researchers are interested in is not the response time itself. However, in many instances the influence of changes in-between single trials is of interest and it is important to know what participants expected in every single trial to obtain the data that are of interest for the specific research question. Cues that are presented in order to induce expectations achieve this goal with the additional advantage that the researcher has full control over what the participant is supposed to expect. In contrast, self-generated expectations cannot be directly manipulated by the researcher in every single trial, but they can be measured. Still researchers have some influence on self-generated expectations. For example, overall frequency manipulations can influence how often a certain event is expected over the course of the entire experiment or the stimulus can be adapted on a trial-by-trial basis to achieve the expectation (mis)matches necessary for the specific research question. Some studies use questionnaires to find out about participants' expectations. For example, Jiménez and Méndez (2013) asked participants about their expectations and the strength of the expectations with a 6-point Likert scale after each trial during one part of the experiment. While this allowed for precise assessment of the expectations, the inclusion of the 6-point Likert scale influenced the temporal succession of trials which was relevant for the research question. This forced them to compare the expectation effects from one set of trials to the response time effects from another set of trials which influenced their interpretation of the results (see also Publication D). Spontaneous verbalizations of self-generated expectations that are prompted and integrated into the course of the trial do not disturb the temporal sequence within trials very much and not any more than presenting cues does. This makes them ideal to use when temporal processes play a role and the best comparison to cue-induced expectations. All publications included in this thesis compare verbal self-generated expectations to (verbalized) cue-induced expectations. While this helps to gain insight into the processes underlying the expectations and how they differ and interact, the results are also relevant from a methodological perspective as an aid to decide what operationalization of expectation is appropriate for which (type of) experiment.

Acosta has already shown in 1982 that self-generated expectations show larger expectation mismatch effects for behavioral parameters than cue-induced stimulus expectations. This has since been replicated several times and also shown for EEG effects, for conflict expectations, if diverging response incentives exist (Umbach et al., 2012) and for a verification task (Publication B) instead of a stimulus response task. Thus, the research that compares self-generated expectations from one set of trials to cue-induced expectations from another set of trials indicates that when aiming for large expectation effects it is advisable to choose self-generated expectations over cue-induced expectations in the experimental setup. An aim for large expectation mismatch effects is for example relevant because the aim of the study is to find out how certain variables influence expectations and the underlying effects have to be large enough so that a differentiating effect of higher order interactions can be measured.

The results of Publication C show that if both expectations are combined within one trial the mismatch effect of self-generated expectations is still the largest mismatch effect even if diverging cues are presented that point towards a different stimulus than the one expected (through self-generation). Furthermore the effect of self-generated expectations cannot be enhanced additionally by cues indicating the same stimulus as the self-generated expectations. The effects of cue-induced and self-generated expectations are not (over)additive if combined within one trial. When aiming for large expectation effects (for example because researching the modulation of expectation effects through certain variables) it is sufficient to use self-generated expectations, additionally using cues does not enlarge the effects.

4.1 Conflict Expectations and How Measuring Self-Generated Expectations Can Help to Investigate the Influence of Expectations on the Sequential Congruency Effect (SCE)

In Publication D I investigated the difference of self-generated and cue-induced conflict expectations in a Stroop task. The investigation of conflict expectations is of special interest because the role of expectations has been discussed in the literature on the Sequential Congruency Effect (SCE) since its discovery and has also been a topic of debate in a recent scientific discussion about self-generated conflict expectations (Duthoo, Wühr, & Notebaert, 2013 vs. Jiménez & Méndez, 2013, 2014). The first order conflict effect found in many paradigms (e.g. Stroop, Flanker) shows that humans tend to be slower and make more mistakes in conflict trials than in congruent trials. The SCE describes a higher order conflict effect: the modulation of the conflict effect by the amount of conflict in the previous trial(s). A conflict effect is usually found to be smaller after (a row of) conflict trial(s), while it is larger after a (row of) congruent trial(s). The SCE is also known under several other terms including congruence sequence effect, Gratton effect, and conflict adaption effect, the last of which already includes an indication to the (presumed) source of the effect or rather limits the view to only a part of the effect. I chose SCE as a neutral descriptive term for the effect. When Gratton, Coles, and Donchin (1992) discovered the effect, they already suggested repetition expectations to be responsible for it. Other approaches, like the conflict monitoring theory (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999) propose that previously experienced conflict gives feedback to control processes. Somewhat combining the debate whether the SCE is due to rather proactive or reactive processes, Notebaert, Gevers, Verbruggen, and Liefooghe (2006) propose that the SCE is made up of two components, a slower top-down process and a fast bottom-up process. In this model, the former would be accessible for and influenced by expectations, while the latter is independent of expectations and (only) influenced by repetitions.

However, the question whether expectations play a role in the SCE is still a topic of scientific discussion. Duthoo et al. (2013) and Jiménez and Méndez (2013; 2014) investigated the influence of self-generated expectations on the SCE in a Stroop paradigm with seemingly contradictory results. Jiménez and Méndez (2013; 2014) found diverging effects for expectations (gamblers fallacy for a row of trials with the same conflict level, for example a tendency to expect an incongruent trial after a row of congruent trials) and response times (a larger Stroop effect after a row of congruent trials). In addition, Jiménez and Méndez (2013) set the Response-Stimulus-Interval to zero, enabling little time for expectations to develop but still found a (large) SCE. Thus, they argue that the SCE is not influenced by expectations. In contrast, Duthoo et al. (2013) only found a SCE for trials in which the participant expected a repetition of conflict level. However, both the experimental setup and the type of analysis differed between the studies of Duthoo et al. (2013) and Jiménez and Méndez (2013; 2014).

The aim of Publication D was to allow for both types of analysis to see whether the results could be consolidated, as well as to compare whether self-generated and cue-induced conflict expectations had similar or diverging influence on behavior, especially the SCE. We followed the methodology of Jiménez and Méndez (2014) to allow for a better comparison. We used the same method to manipulate consecutive rows of trials with similar or changing congruency and we also used four colors/words in two pairs to exclude repetition-based explanations of the SCE. In contrast to Jiménez and Méndez (2013; 2014) we measured expectations verbally, allowing for the expectations and response time results from the same trials to be analyzed. We also added a condition where we cued participants instead of letting them form self-generated expectations.

We could replicate and consolidate the results of both Duthoo et al. (2013) and Jiménez and Méndez (2013; 2014). Like Duthoo et al. (2013) we found the SCE only for trials for which participants had expected a repetition of conflict level. However, we could not find this effect in the cue condition. Cue-induced expectations did not seem to influence the SCE, at least for cues of such a low validity as in our study (while self-generated expectations of similarly low validity did influence the SCE). The effect for self-generated expectations was mainly driven by especially fast responses for congruent match trials for which participants had expected a repetition of conflict level, i.e. the previous trial was congruent, participants expected a congruent trial and the upcoming trial was indeed congruent (while there was no relating strong RT disadvantage for correspondent incongruent trials). While an *adaption to the lack of conflict* has been previously theorized (Lamers & Roelofs, 2011; Schlaghecken & Martini, 2012) as one of the mechanisms behind the SCE, we found evidence that specifically this adaption to the lack of conflict rather than the adaption to conflict is driven by self-generated expectations. Similar to Jiménez and Méndez (2013; 2014) we compared the development of expectations over a run of trials with the same conflict level to the development of the SCE over a run of trials with the same conflict level. After one trial of the same conflict level participants on average showed a repetition bias, which was weaker after two consecutive trials of the same congruency level and switched to a gambler's fallacy (expectation of a congruency level change) after three consecutive trials of the same congruency.

When only analyzing trials after just one congruent vs. incongruent trial we found no SCE. This is in line with other studies that demonstrate that this first order SCE can only be found for tasks with (partial) feature repetitions (which we excluded by using four different colors in our Stroop task). For the rows of consecutive trials with the same congruency level we found a higher order SCE, i.e. for more congruent trials in a row the Stroop effect got larger (similar for two and three congruent trials) and the more incongruent trials had preceded the current trial the smaller the Stroop effect was in the current trial. Thus, we could replicate the diverging pattern between expectations and higher order SCE that Jiménez and Méndez (2013; 2014) had found. We can rule out that the seemingly contradicting results of Duthoo et al. (2013) vs. Jiménez and Méndez (2013; 2014) were due to differences in experimental procedure since we obtained similar result patterns within the same data set.

Conclusively it can be said that we found different components of the SCE within the same experiment: A bottom-up adaption effect influenced by previously experienced conflict that does not seem to be accessible to expectations (or even points in the opposite direction as expectations would indicate) and also a more top-down "adaption to the lack of conflict" that is driven by (non-conflict, repetition) expectations that have been self-generated. Not only did measuring verbalized (low validity) self-generated expectations allow for a specific expectation effect to be found, but also the data obtained with this methodology allowed for both types of analysis: The one used by Duthoo et al. (2013) and the one used by Jiménez and Méndez (2013; 2014) and thus consolidating the (seemingly) contradictory results of these studies. Verbalized self-generated conflict expectations showed a stronger influence on the SCE than cue-induced expectations (who showed no influence) and also proved to be the methodological approach appropriate to measure expectations in this setting to settle a scientific debate. The measurement of verbalized self-generated conflict expectations could be used to determine which component of the SCE is accessible to expectations, while also other components of the SCE could be measured that were not expectation-driven. This shows the advantages of using self-generated verbalized expectations as a measurement for expectations in scientific research. The null effects for cues also show that using (only) cues instead would not have helped to investigate this research question.

4.2 Modulations of Successive Expectations

The results of Publication D show that for conflict expectation the previous trial can have modulating effects on the successive trial and that these interact with the expectation. For this specific experiment (with low validity conflict expectations) only self-generated expectations but not cue-induced expectations showed this modulating effect. However, the SCE is itself an effect that is based on modulation (of conflict) from the previous to the current trial and the expectations were analyzed in relation to this. The modulation concerned the conflict effect (in relation to the expected conflict level) rather than the expectation effect itself. For stimulus expectations a modulating influence from a previous to a current trial is related to the mismatch effect itself. If the mismatch effect is smaller after mismatch trials compared to match trials this shows that the expectation has less influence if the previous expectation was wrong (because the expectation is trusted less and thus transferred less into action).

In Publication C we analyzed how self-generated and cue-induced expectations modulated the effect of the subsequent expectation, not only for the same type of expectation but also for the different type of expectation, respectively. For self-generated expectations the mismatch effect was smaller if the self-generated expectation did not match in the previous trial than if it did match. Cue (mis)matches showed no modulating effect on the cue mismatch effect in the subsequent trial. Neither was the cue mismatch effect influenced by whether the self-generated expectation matched in the previous trial nor was the self-generated expectations mismatch effect modulated by whether the cue matched in the previous trial. While self-generated expectation effects were large, despite rather invalid self-generated expectations (under 50% match rate; match rate on average at chance level), they were still modulated by whether the self-generated expectations were fulfilled in the previous trials or not. Self-generated expectations (of low validity) can thus be used somewhat adaptive depending on how the expectation performed previously. In contrast the cue of similarly low validity had a smaller mismatch effect which was not adaptive concerning the previous performance of the cue. When researching how adaptive expectation processes work, self-generated expectations seem to be the better option than cue induced expectations, at least for low validity expectations. While it seems to be possible to rely more or less on the self-generated expectation, depending on whether the previous self-generated expectation came true, participants do not seem to either switch to relying more on another type of expectation if one type of expectation was not fulfilled nor to rely less on all types of expectations if one type of expectation was not fulfilled. This should be taken into consideration when deciding about how expectations are operationalized when researching modulating effects of expectations.

4.3 Cues Show Small(er) but Stable (Priming) Effects

All results previously described indicate advantages of self-generated expectation over cues when operationalizing expectations in psychological experiments. However, cues are still commonly used when researching expectations and they have the advantage of more experimental control - participants can be cued what to expect in every single trial. It can be questioned whether cues, especially if they are of low validity, really have any effect if participants do not expect what the cue indicates. As an explanation of the stronger effect of self-generated expectations Gaschler and Schwager et al. (2014) proposed that cues only elicit expectations in a subset of trials. Accordingly averaging response time results over trials where the cues elicited an expectation and over those where cues failed to do so leads to smaller mismatch effects (than in the trials where a self-generated expectation is formed, verbalized and thus measured in every single trial). It is even possible that in some trials participants form a diverging expectation (especially if cues are of low validity and/or a cue in a specific trial indicates an event of low probability) that further diminishes the effect of the cue when these trials are averaged with the trials where the cue fulfilled its purpose. This challenges the idea whether cues are ever the adequate operationalization to induce expectations in psychological research because cue effects might just be watered down self-generated expectation effects. In Publication C participants were both cued and asked to verbalize their self-generated expectation within the same trials, which allowed observing whether the cue effects were influenced by affirming or contradicting self-generated expectations. While the cue mismatch effect was smaller than the self-generated expectation mismatch effect it was stable across all expectation conditions. The response time difference between trials where a cue matched or mismatched the presented stimulus was very similar regardless of whether the participants were not asked to verbalize a self-generated expectation, verbalized a (diverging) self-generated expectation after cue presentation or verbalized it before cue presentation. The participants were relatively uninfluenced in their self-generated expectations by the cues in the condition where they first saw the cue and then verbalized their self-generated expectation. Their self-generated expectations differed from the cue in more than 50% of the trials; still the overall cue mismatch effect was not diminished. If the cues influenced the expectations only in a subset of trials the averaged mismatch effect of the condition in which participants only saw a cue should be larger than the difference between trials where the cue matched and the self-generated expectation mismatched the presented stimulus vs. those where both mismatched. In the former case trials where the cue was able to influence the self-generated expectations (and thus lead to larger effects) would be averaged with trials where the cue did not succeed to do so, while in the latter case only trials where the cue did not succeed to do so (and thus a diverging self-generated expectation was verbalized) were included. This was not the case[1].

Cue-induced effects are not just a less precise (because cues don't influence expectations in every single trial) version of self-generated expectation effects and cue effects are stable even if diverging self-generated expectations exist. Thus, if the higher experimental control that cues can offer is necessary they can be used without worrying whether possible diverging self-generated expectations disturb the results. However, the results also mean that cue effects cannot be generalized for other (i.e. self-generated) forms of expectations because the processes underlying cue-induced effects do not seem to be accessible to verbal report of the participant's expectation.

5 Qualitative Differences of Cues and Self-Generated Expectations

In the previous section I have discussed how the results of the publications included in this thesis relate to operationalizing expectations in psychological research. But the differences between the effects of self-generated and cue-induced expectations found in the

[1] This relation is not explicitly described in Publication C. The mismatch effect in the only cue condition is $M\Delta$ = 35.9ms. For the double expectation conditions the difference between full mismatches (both cue and self-generated expectations did not match the stimulus) and cue matches (self-generated expectation mismatches) is $M\Delta$ = 36.7ms (for the condition with first the self-generated expectation and then the cue) and $M\Delta$ = 34.7ms (for the condition with first cue and then the self-generated expectation)

publications do not only help to decide under which experimental circumstances which type of expectation operationalization is adequate, they also lead to the conclusion that the cognitive processes underlying these expectations are not the same. I have shown that self-generated expectation effects differ quantitatively from cue-induced effects, for different experimental setups and types of expectations the former are larger than the latter. In the following section I discuss how self-generated expectations and cue-induced expectations also differ qualitatively and how this relates to theories about psychological processes.

5.1 Self-Generating Expectations Puts the Expectation in the Focus of Attention in Working Memory

It has been proposed by Gaschler and Schwager et al. (2014) that the larger effects of self-generated expectations are caused by a representation of the expected object (event/stimulus) in the focus of attention in working memory (Oberauer, Souza, Druey, & Gade, 2013). While cues are not in the focus of attention and can even be ignored if they are of low validity (Adam, Bovend'Eerdt, Smulders, & Van Gerven, 2014; Alpay et al., 2009) self-generated expectations lead to a large expectation effect even for expectations with a low validity (Acosta, 1982, Gaschler and Schwager et al., 2014 and Publications B-D) because the process of self-generating puts the expected object into the focus of attention. Hacker and Hinrichs even found mismatch effects for stimuli that participants explicitly did not expect (1979) or expected less than another stimulus (1974). Just the process of self-generating an expectation, even a "non-expectation" seems to focus the attention on the (not) expected object.

The results from the publications in this thesis concur with this explanation. While previous studies had already shown that the expectation effects differ for low-validity expectations the results of Publication B showed that this was not due to entirely ignoring the cues. The verification task in Publication B forced participants to process cues for the execution of the task. Processing the cues could mean that the object they cue are put in working memory - however not into the focus of attention in working memory but rather as a peripheral component (cf. Lewis-Peacock, Drysdale, Oberauer, & Postle, 2012). In contrast, the self-generated expectations are put in the focus of attention in working memory and subsequently elicit larger (behavioral) effect.

A stronger representation in working memory than the focus of attention is not possible. Thus if the previous explanation is the cause of the larger effects of self-generated expectations compared to cues, it should not be possible to enhance them. Competing stimulus/response options exist at the beginning of a trial, the self-generated expectation singles out the strongest option and puts the focus of attention on this stimulus/response option in a "winner takes it all" principle. In the experiment in Publication C cues and self-generated expectations were combined within one trial and indeed the effect of self-generated expectation matches could not be enhanced by additional matching cues. If self-generating an expectation about a certain stimulus puts this stimulus into the focus of attention in working memory, an additional cue also pointing towards this stimulus cannot add anything to it. The result is that cue and self-generated expectation effects do not operate additively. The effect of self-generated expectations (alone) is the strongest mismatch effect that can be found even when combining both types of expectations. This concurs with the focus of attention in working memory explanation. When participants are first cued and then formulate a (possibly diverging) self-generated expectation the response time advantage for self-generated expectation matches is not diminished by a differing preceding cue or enhanced if the cue also pointed to the matching stimulus. The focus of attention is on the self-generated expectation irrespective of the previous cue. However, when the temporal order of the two types of expectations is reverse the effect of self-generated expectations is smaller. If a participant verbalizes a self-generated expectation and is afterwards cued the response time advantage of a self-generated expectation match is diminished if the cue indicated a different stimulus. Notably also if the cue points to the same stimulus as the self-generated expectation this “double match” of expectations leads to slower response times than if the order of expectations was reversed. This mismatch effect (both cue and self-generated expectations match the stimulus vs. both mismatch the stimulus in the condition in which the cue is presented after the self-generated expectation is verbalized) is also smaller than the self-generated expectation mismatch effect from trials without any cues. While self-generating an expectation puts the expected object into the focus of attention a subsequent cue (or other event) might shift the focus of attention away from the self-generated expectation, (on some trials) even when the cue indicates the same object as the self-generated expectation. The cued object is not put into the focus of attention thus leading to slower “double match” trials compared to trials with only self-generated expectations or trials where the self-generated expectation is formed and verbalized after the cue. Thus the results of Publication C are in line with the explanation that the larger effects of self-generated expectations are caused by a representation of the expected object in the focus of attention in working memory while cues are represented more peripherally.

5.2 Internally vs. Externally Triggered Expectation Modes

Research on action-effect anticipation has shown that different kinds of action modes exist for internally triggered and externally triggered actions (Herwig & Waszak, 2009, 2012; Obhi & Haggard, 2004; Pfister, Kiesel, & Melcher, 2010). When one hypothesizes that cues lead to externally triggered expectations while self-generated expectations are internally triggered this could mean that similar to different types of action modes also different types of expectation modes exist. Competing action modes hamper rather than improve action execution (Astor-Jack & Haggard ,2005; Obhi, & Haggard, 2004). In the respective experiments participants were asked to execute a certain movement at any time they wanted to (internal impulse) and additionally, they should execute the movement whenever an external trigger was presented. When the movement was executed due to an internal impulse and an external trigger was presented at the same time as the internal impulse, the execution of the movement was delayed compared to instances where the participants only acted due to their internal impulse. The authors explained the effect for this “truncation” condition by the necessity to switch from an internally generated action mode to an externally triggered mode. In Publication C the condition in which participants first verbalize a self-generated expectation and are then presented with a (possibly diverging) cue could be seen as similar in the sense that an internally triggered expectation mode is “truncated” by an externally triggered expectation mode. For this comparison trials in which cue and self-generated expectation are identical and both match the appearing stimulus are of special interest. These are the trials for which both - cue and self-generated expectation - indicate the same stimulus so that when it appears responses should be especially fast. Instead the mismatch effect for these “double matches” (compared to “double mismatches”) is smaller than the mismatch effect in the condition with only self-generated expectations and these double matches are slower than double matches for a reversed order of the two types of expectations. While the condition most similar to the research about competing action modes (an internally triggered action mode is truncated by an externally triggered action mode) leads to comparable results (an internally triggered expectation mode is truncated by an externally triggered expectation mode) another part of the results also challenges this comparison of effects and possible underlying mechanisms. At least if the cue and the self-generated expectation differ (irrespective of the temporal order) both types of expectations still lead to mismatch effects. Thus no expectation mode is active alone which puts in question the assumption of a (complete) expectation mode switch that happens if both expectations point towards the same stimulus. If both expectation modes operate in parallel it is still possible that the activation of a second, externally triggered, expectation mode hampers the first but this explanation is less clear cut. Additionally, if the self-generated expectation is verbalized after the cue no decrease of mismatch effect (compared to self-generated expectations alone) can be found. Thus it might be more appropriate to consider the mismatch effects caused by cues and self-generated expectations a result of two distinct underlying processes rather than just two different types of (competing) expectation modes.

5.3 Are Effects from Cues Really Expectation Effects?

In this entire thesis I write about self-generated expectations vs. cue-induced expectations however it is a legitimate question whether the effects elicited by cues are really expectation effects or due to a different process e.g. priming.

While previous research and the other publications in this thesis show smaller effect for cues than for self-generated stimulus expectations the experiment in Publication D showed a mismatch effect for self-generated conflict expectations but no mismatch effect for cues[2]. This finding fits to the idea that "cue-induced expectation effects" are rather due to priming than an expectation being formed on the basis of the cue, as priming a specific stimulus is easier than something abstract like a conflict level.

If cues do not just lead to priming effects but the cue is used to form an expectation, the verbalized self-generated expectations should follow the cues, at least in a large proportion of trials. This was not the case for the according double expectation condition in Publication C. While participants followed the cues to a slightly larger percentage (1.7%) than

[2] The published version of Publication D only contains an analysis of the data with respect to expectations about the repetition of conflict level. However, an analysis with expectations (mis)match as a factor (i.e. whether the self-generated or cue-induced expectation about the upcoming conflict level is fulfilled or not) shows no significant mismatch effect for cues, but only for self-generated expectations.

when they did not know the cue beforehand this difference was only small and participants in more than 50% of trials still expected another stimulus than the one the cue indicated. This could mean that cues do not lead to (self-generated) expectations but it could also be an artifact of the instruction, thus it is not sufficient as the only indicator for cues not leading to expectations. Participants were instructed to verbalize their “true” expectations, not to deliberately always verbalize the same stimulus the cue indicated even if they expected something else, nor to always contradict it out of principle. While this instruction was used with the aim to ensure unbiased self-generated expectations that only followed the cue if the participant truly expected the cued stimulus there is no way to ensure whether this instruction succeeded. The instruction might have confounded the results and lead participants to change their (self-generated) expectations away from the cue in more trials than they would have done without the instruction (and without the need to verbalize a self-generated expectation).

However, the response time results in Publication C also indicate that the process underlying the cue mismatch effect is relatively independent from the effect of the additional self-generated expectations. The cue mismatch effect was small but stable and not diminished if a (diverging) self-generated expectation was verbalized. This, in combination with the result that the effects of cue and self-generated expectations were not additive, indicated that the process underlying the cue mismatch effect is distinct from the process underlying the self-generated expectation mismatch effect. While one might assume that two entirely distinct expectation processes exist with the process triggered by cues not being accessible for verbal report if the (self-generated) expectation is asked for (although the cue itself can be reported if asked for), this assumption is not the most parsimonious. The respective data also fits a model in which the cues lead to small but stable mismatch effects through priming, but not to “cue-induced *expectations*” while self-generated expectations lead to (larger) expectation mismatch effects (because the expected object is in the focus of attention in working memory while the primed/cued object is represented more peripherally in working memory).

6 Conclusion

Expectations are of interest for psychological theories because they influence responsive action and more generally human behavior, this is especially true for self-generated expectations. The studies included in this dissertation replicated the previously found stronger effects of self-generated compared to cue-induced expectations. The methods used in these studies allowed to better eliminate alternative explanations for this difference of effects (e.g. not due to ignorance of the cues), to generalize this finding (from stimulus to conflict expectations) as well as to indicate a qualitative difference of the two expectation formats and to gain further insight into this difference. Letting participants verbalize self-generated expectations is an adequate operationalization for measuring expectations, especially in comparison to inducing them via cues, and can sometimes even consolidate diverging results gained with different expectation operationalizations. Self-generated expectations show stronger expectation (mismatch) effects than cues, not only for simple stimulus expectations but also for more complex life-like stimuli with task-irrelevant features expectations and for more abstract conflict expectations in contrast to stimulus expectations. This difference holds true if cues have to be processed to complete the task and it does not simply show up because cues might be ignored more easily than self-generated expectations. An open research question that remains is whether explicitly instructing participants to verbalize expectations enhances expectation (effects) above the level that they have when generating expectations in everyday life. One aspect is that expectations are not always verbalized and self-generated expectations that people only think about might be additionally enhanced by verbalization. This could be investigated by a comparison of implicitly measured (but self-generated, not cued) expectations to verbalized self-generated expectations (and to cues). Another aspect is that in everyday life expectations are often more diverse with varying timing between expectation, stimulus und response; and much more complex and changing stimuli and responses. Before the results can be generalized, (field) experiments should include these varying aspects. However, many psychological studies currently using cues to investigate expectations are conducted in a very simplified setting in a lab environment, so here the results of this dissertation can be applied.

Self-generated expectations do not only lead to quantitatively stronger effects than cues but the results also indicate that they differ qualitatively, because self-generating an expectation puts it in the focus of attention in working memory. Further research that specifically manipulates attention to different degrees while the expectation is verbalized (or also for non-verbalized expectations) might be fruitful to further test this explanation.

In spite of these stronger self-generated expectation effects cues show small but stable effect, even if diverging self-generated expectations exist. This makes cues an adequate tool when their higher experimental control/ malleability is needed. However, these cueing results should at the most be very cautiously interpreted as expectation results but rather as effects due to, for example, priming.

Clark's predictive coding model (2013) ultimately views all processes as having a basis in prediction/expectation on different levels (hierarchies), also those levels that are not consciously accessible (for report). If this model is correct the self-generated expectations measured in this thesis would lie on a very high level (of abstraction within this hierarchy) which is introspectively accessible. According to Clark, only prediction errors are processed and used to adapt the predictive models (and prevent predictive errors in the future). In this sense self-generated expectations do not act according to Clark's model. While expectation mismatches generate high (response time) costs (thus the expectations seem to be relied on) the expectations are not changed in order to minimize mismatches (probability matching of stimuli frequency instead of always expecting the stimulus with the highest frequency). Self-generated expectations in an experimental setting persist even if they are disproved again and again (by mismatch trials). In a graver clinical context prevailing expectations despite contradicting evidence exist for example for phobias when confronting anxieties (without something awful happening), and the expectation that something awful will happen (i.e. the anxiety) persists despite being "disproven" by the experience, or when a negative outlook on life is maintained by a depressed patient even though positive life events occurred. Integrating the instances where predictive models are not adapted after prediction errors is one of several open research questions that need to be answered in order to explain all processes in the brain with an "hierarchical prediction machine". How self-generated verbalized expectations and their strong mismatch effect and low adaptability (strong mismatch effect even for low validity expectations) can be integrated into this model remains open. However, verbalized self-generated expectations certainly pose a method to explicitly measure expectations and their effects directly.

The strength of self-generated expectation effects (despite a low validity) can help us, for example when expecting events that are very rare but have very negative effects if we do not respond to them correctly in time. One example is a sudden reason to brake in an otherwise clear and innocuous traffic situation. Applied research could investigate how self-generated expectations about low frequency/high risk situations can improve the correct/fast response to these events and possibly in a next step what is necessary for people to self-generate these specific expectations instead of just cueing people to be aware of the specific event (for example with a road sign as the cue).

Finally, we should also keep in mind that self-generated expectations influence us strongly in situations where they turn out to be wrong. Also scientists are not immune to expectation effects influencing our perception of data and thus our theories (Brewer, 2012) and it is advisable to stay conscious of one's own expectations and their strong influence on behavior.

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Eidesstattliche Erklärung

Hiermit erkläre ich an Eides statt,

1. dass ich die hier vorliegende Arbeit selbstständig und ohne unerlaubte Hilfe verfasst habe,

2. dass ich mich nicht anderwärts um einen Doktorgrad beworben habe und noch keinen Doktorgrad der Psychologie besitze,

3. dass mir die zugrunde liegende Promotionsordnung der Mathematisch-Naturwissenschaftlichen Fakultät II vom 17.01.2005, zuletzt geändert am 03.08.2006, veröffentlicht im Amtlichen Mitteilungsblatt der Humboldt-Universität zu Berlin, Nr. 34/2006, bekannt ist.

Berlin den 06. Mai 2019

Maike Kemper

Appendix

Article A

Kemper, M., & Gaschler, R. (2017). Self-Generated or Cue-Induced—Different Kinds of Expectations to Be Considered. *Frontiers in Psychology*, *8*.

https://doi.org/10.3389/fpsyg.2017.00053

Article B

Kemper, M., Gaschler, R., & Schubert, T. (2017). Stronger effects of self-generated than cue-induced expectations when verifying predictions in data graphs. *Journal of Cognitive Psychology*, 1-16.

https://doi.org/10.1080/20445911.2017.1291644

Article C

Kemper, M., Gaschler, R., & Schubert, T. (in preparation). What should I expect? How self-generated predictions and cue-induced expectations interact.

Article D

Kemper, M., Gaschler, R., Schwager, S., & Schubert, T. (2016). The benefit of expecting no conflict—Stronger influence of self-generated than cue-induced conflict expectations on Stroop performance. *Acta psychologica*, *163*, 135-141.

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What should I expect? How self-generated predictions and cue-induced expectations interact.

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Abstract

Prior studies have documented stronger behavioral and EEG effects of self-generated as compared to cue-induced expectations. A strong test of whether cueing and self-generated predictions differ qualitatively or in strength has been lacking so far as prior studies have compared trials that contained only one form of expectation rather than directly pitting one form against the other. This study investigates the differences and interactions of cue-induced expectations and predictions within the same trial in a within subjects design. Participants completed a stimulus response task with different expectation condition blocks. In addition to blocks that only contained cues and blocks in which participants were only asked to verbalize their predictions, we added blocks in which both types of expectations were relevant within the same trials. Self-generated expectations lead to stronger effects than cue-induced expectations. Yet, the effects of cues and self-generated expectations did neither add up, nor was the effect of the cues eradicated by (differing) self-generated expectations. The results suggest parallel operation of and qualitative difference between the two forms of expectations.

Keywords: self-generated expectations, cue-induced expectations

What should I expect? How self-generated predictions and cue-induced expectations interact.

Expectations about future events help to prepare appropriately for these events. Although expectations can be differentiated from other processes like automatic response activation (Perruchet et al., 2006), both, responses to stimuli as well as learning processes are aided by expectations (e.g. Dale et al. 2012). Previous studies have shown that self-generated expectations (predictions)[1] have a much stronger influence than cue-induced expectations on reaction times and error rates (Acosta, 1982) as well as Event related Brain Potentials (ERPs) (Kemper et al., 2012). For a review that also includes discussions about expectation effects concerning responses (e.g., Notebaert et al., 2009), task sets (e.g., Duthoo et al., 2012), conflict level (e.g., Alpay et al., 2009; Duthoo et al., 2013, Kemper et al. , 2016), and action effects (e.g., Kühn et al., 2010) see Gaschler et al. (2014).

Evidence for qualitative differences among the variants of expectation is limited (cf. Gaschler et al. 2014) as prior studies have compared cues and predictions by comparing trials in which expectations about an upcoming stimulus (or task, or conflict level) were cue-induced to trials in which participants were asked to verbalize their predictions. To our best knowledge until now no study has directly pitted cue-induced expectations and predictions against each other within the same trial. Such an approach can build upon work by Mattler (2005) combining different cues. Mattler (2005) has proposed a model to explain interacting

[1] As a note on terminology: Previous studies have used different terms synonymously (for example expectation and prediction) or also as a form of differentiation between different types of expectations (for example prediction only meaning self-generated expectations but not cue-induced expectations). Different publications have used diverging terminology. In this study we use cues similar to other studies with the intention to induce expectations. As you can see in the Discussion section it is debatable whether cues really induce expectations (in every single trial) or whether the cue effects might rather be due to processes like priming (at least in some instances). Nevertheless we will use the term *cue-induced expectations* in this manuscript. Where fitting we use the shorter term cue or cueing. When talking about different expectation conditions we always also mean the conditions that use cues with the aim to induce expectations. The general term expectation is used as an umbrella-term that can mean different types of expectations. We do not use prediction as a general term for expectations but use it only as a synonym for self-generated expectations (this allows for shorter sentences and

and additive effects of different types of (expectation-inducing) cues. When upcoming stimuli and upcoming responses were each cued, a mismatch on one level (e.g. cued stimulus expectation not met) could lead to a cancellation of other cue-based preparatory processes. While Mattler (2005) combined different cues in one trial we combine self-generated predictions and cues in the same trial. By using verbalized cues and verbalized, self-generated predictions within the same trial we test whether the effects of the different types of expectations are cumulative or whether one form dominates the other. While past studies (e.g., Acosta, 1982; Kemper, Gaschler, Schwager, & Schubert, 2016) have contrasted blocks with cue-induced expectations with blocks with self-generated expectations, we now additionally include blocks where both kinds of expectations are relevant in the same trials, one block in which each trial begins with the cue and one block in which each trial begins with the self-generated prediction. The effect of expectations is assessed based on the RT differences between trials in which the upcoming stimulus (mis)matches one or the other or both forms of expectations.

Pitting either form of expectation against each other within the same trial can help to distinguish between two possible accounts for the established finding of stronger effects for predictions than cue-induced expectations. The more parsimonious account would suggest that there is just one kind of expectation, yet cues vs. self-generated predictions differ in the likelihood of eliciting an expectation. Either kind of expectation can lead to the same preparatory state, yet there are differences in the extent of preparation or the likelihood of triggering preparation. For instance, low validity cues might very often be ignored or might influence preparation only to a small extent (e.g. Alpay, Goerke, & Stürmer, 2009). Yet, apparently participants cannot help but use even low validity predictions for preparation (e.g., Schwager, Gaschler, Rünger, & Frensch, 2017). Accordingly one could assume that there is only one type of expectation: This type of expectation can be influenced by cues in some

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easier reading, especially in the results and the description and comparison of the different expectation trials while for other trials cues are not able to (sufficiently) influence the expectations making cues an imprecise manipulation of expectations. If cues and self-generated predictions tap (with different efficiency) into the same preparatory processes, then effects of cues and predictions could potentially add up when these forms are combined within one trial. When, for instance, both point towards the same stimulus and this stimulus indeed appears, reaction time should be faster than when only one form of expectation points towards the stimulus. Accumulation can be expected to work irrespective of order. Whether the cue follows the prediction or the cue is presented before the prediction is made should not determine whether effects can add up.

Another way to explain the previously found stronger effects of predictions as compared to cues is the assumption that making people form and verbalize a prediction has the effect that the object of prediction is represented in the focus of attention in working memory (Oberauer et al., 2013¸ Gaschler et al., 2014). This privileged form of representation leads to the strong behavioral effect. One early finding arguing for privileged representation in working memory is the set-size manipulation by Acosta (1982). While in cueing blocks, the RT advantage of trials in which the stimulus matched the (cued) expectation was the smaller the larger the set of stimuli in the block, no pronounced fan effect was observed in blocks with self-generated verbalized expectation. While verbalizing a prediction seems to mandatorily lead to strong preparation effects even under adverse circumstances such as low validity and lack of response-relevance (Schwager et al. 2017), cueing might not secure privileged representation. Rather, cues might lead to smaller effects through automatic priming (of the cued stimulus), mostly outside the focus of attention in working memory. Such a qualitative difference between cue-induced vs. self-generated expectations would cast doubts upon whether cue-effects and prediction-effects should add up. A strong representation in working memory might not be strengthened further by a cue. Rather, it might dominate

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conditions).

potentially conflicting cueing. Non-additive effects of predictions and cues would coincide with the assumption that predictions and cue-induced expectations lead to qualitatively different preparatory processes, rather than only differing in likelihood or strength of engaging in preparation.

Support for a qualitative difference between cue-induced and self-generated expectations might be derived from the literature on action-effect anticipation. Internally triggered and externally triggered expectations have been reported to lead to different types of action modes (e.g.: Herwig & Waszak, 2009, 2012 ; Obhi & Haggard, 2004; Pfister, Kiesel, and Melcher, 2010). For instance, Astor-Jack and Haggard (2005) showed that one and the same finger press was delayed rather than speeded in case an external trigger commanding this movement and an internal impulse to exert it by chance coincided. Thus, different types of expectations might compete rather than accumulate. This could manifest in RT effects but also show in the likelihood with which predictions confirm or contrast with the previously presented cue.

Additional evidence concerning whether or not cues vs. self-generated expectations feed into the same kind of preparatory processes might be derived from scrutinizing sequential modulations. The impact of expectations is modulated depending upon the (mis)match of expectation in the previous trial (cf. Duthoo et al., 2013; Kemper et al., 2016; Schwager et al. 2017). Here we can test whether (mis)match in one or the other kind of expectation leads to a general or a specific modulation of the current trial.[2]

Methods

Participants

[2] Note that we conducted a pilot study to check whether the measurement of verbalized self-generated expectations and cueing within the same trial was feasible and whether the results could be compared to trials in which participants were either only cued or only asked to verbalize their predictions (Pilot study in the Appendix).

Of the 28 participants that were originally tested, the data of five were excluded. Two participants had to be excluded due to experimenter error (they did the same blocks in both experimental sessions and thus their data was incomplete). One participant discontinued participation in the second session. One participant expected the same stimulus (stimulus with the highest probability) in all trials for the self-generated expectations and one participant had problems understanding the task[3]. The data of twenty-three participants (mean age of 26.1, *SD* = 5.38 years) was used for analysis. All had normal or corrected-to-normal vision. The participants were either psychology students at Humboldt-Universität zu Berlin and participated in exchange for course credit or received a compensation of 24 € for participating in two experimental sessions with a duration of approximately 90 minutes each. For coming to the second session they received an additional 10 €. Participants gave their informed consent prior to the experiment.

Apparatus and Software

The experiment was programmed in Python and Psychopy (Peirce, 2007) and conducted on a Windows 10 PC. The participants' verbal responses were recorded using a table microphone and their manual responses were recorded using a regular computer keyboard. The experimenter coded the verbalized self-generated expectations during the experiment using three mouse buttons.

Stimulus Material and Experimental Manipulation

The stimuli were three different forms (star, house and cross) which were shown with three different frequencies (60%, 30% and 10%). Which form occurred with which frequency was balanced over participants. In addition, the mapping of the stimuli to the frequencies and

[3] Note that including the data of the three participants with sufficient data points for analysies in the statistical analyses does not affect whether any of the reported effects reach the significance level of 0.05

to the responses was balanced over participants. The stimuli were displayed in the middle of a light grey background and had a width of about 22 mm (equivalent to a visual angle of about 2.1° at a viewing distance of 60 cm).

The experiment consisted of four parts, with the order of the parts being balanced over participants. There were two single expectation parts: The cue condition and the prediction condition. Furthermore, there were two double expectation conditions: The prediction-first-then-cue condition prompted the participants to first verbalize a self-generated expectation and then they read a cue before responding to the stimulus. In the cue-first-then-prediction condition participants first read the cue and then verbalized their self-generated prediction. Due to the length of the experiment it was divided into two sessions, with a minimum break of one day and a maximum break of two weeks between the two sessions. The parts of the experiment were arranged in such an order that one single expectation condition (with 140 trials) and one double expectation condition (with 440 trials) were always grouped together in one session. It was balanced over participants whether the experiment started with the single or double expectation condition in each session and whether the cue-first-then-prediction or the prediction-first-then-cue condition was presented in the first or second session. For the cue condition as well as both double expectation conditions the cues were shown in a (pseudo)randomized order with the same overall frequency as their respective stimulus and with the same frequency of (mis)matches to the three stimuli as would be reached by chance.

Task Procedure and Instructions

The experimenter sat next to the participant during the entire experiment in a two person lab room and coded the predictions of the participant. Before each of the four experimental blocks, participants performed a practice block consisting of 15 trials similar to those in the upcoming experimental block. If necessary, because a participant still had difficulties following the instructions, a practice block could be repeated.

Participants were instructed to verbalize their expectation as soon as an expectation prompt appeared in the middle of the screen. When one of the three possible stimuli appeared, participants had to respond by pressing the key mapped to the stimulus. Participants responded to the stimulus with a button press on the keyboard with their index, middle or ring finger of their dominant hand.

The duration of trials for the single and double expectation conditions was the same. For the two *double expectation blocks* each trial was structured like this: After a 500ms ITI (inter-trial interval) the first expectation prompt (cue or prediction prompt) was presented for 1250ms, followed by a fixation point for 1000ms. Then the second expectation prompt (prediction prompt or cue) was presented for 1250ms, followed by a fixation point for 1000ms. Then the stimulus was presented. If the participants did not respond to the stimulus by pressing a key within 5000ms the trial was counted as an error trial and the next trial started.

For the two *single expectation blocks* each trial was structured like this: After a 500ms ITI the expectation prompt was presented for 1250ms, followed by a fixation point for 3250ms. Then the stimulus was presented. If the participants did not respond to the stimulus by pressing a key within 5000ms, the trial was counted as an error trial and the next trial started. Thus, all conditions were similar in their timing of the expectation(s) as the presentation of the first expectation prompt was always 4500ms before the presentation of the stimulus. For the single expectation conditions, there was only one fixation point (presented longer) during the time in which the second expectation prompt and fixation point were presented in the double expectation conditions. Figure 1 shows the (temporal) trial sequence for one single expectation trial (cue condition trial) and one double expectation trial (cue-first-then-prediction condition trial).

Figure 1.

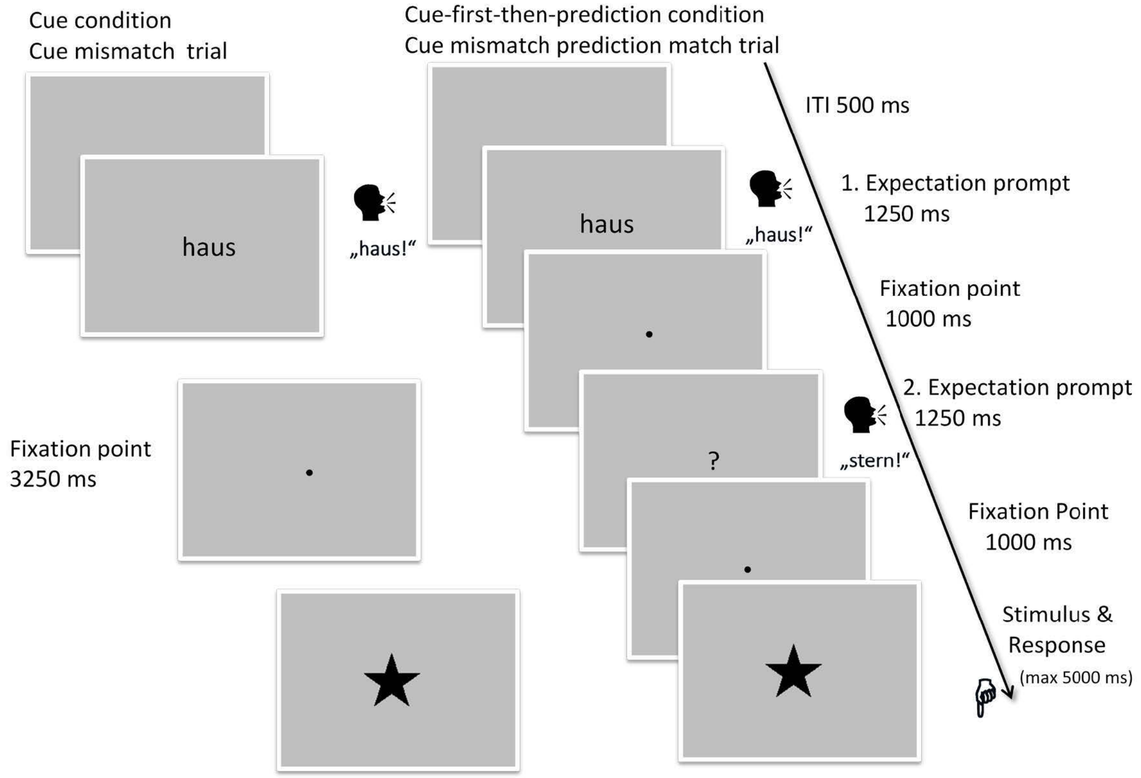

Figure 1 shows the experimental setup for a single expectation (cue only) trial on the left and a double expectation (cue-first-then-prediction) trial on the right. The cue trial is an example of a mismatch trial with the cue indicating the stimulus to be "house", while the stimulus is "star". The double expectation trial is an example of a trial where the cue mismatches the stimulus while the prediction matches the stimulus. The cue indicates "house", however the participant in this exemplary trial verbalizes "star" as their prediction and the presented stimulus is a star to which the participant has to respond by pressing the according button. The arrow on the right indicates the temporal course of both trial types. As can be seen the 3250ms fixation point in the single expectation conditions is the time during which the second expectation is verbalized in the double expectation conditions, separated by two shorter fixation point phases of 1000ms. The temporal distance of the first expectation prompt in the double expectation conditions to the stimulus presentation is thus the same as the time between the expectation prompt and the stimulus presentation in the single expectation conditions.

For predictions the expectation prompt consisted of a "?" question mark, here participants had to verbalize their self-generated predictions. The cues consisted of written words for the three possible stimuli which the participants had to read aloud. For the prediction condition, participants were instructed to verbalize their predictions freely, choosing their prediction from the three possible stimuli. In the double expectation condition in which a cue was presented first, participants were told that either agreeing with or contradicting the cue with their prediction would be fine, and there was no “better” or “more correct” variant. Rather, they should try to say what they really predict.

Results

Data Exclusion

Practice blocks were not analyzed. For the prediction condition and both double expectation conditions, trials in which participants did not verbalize a prediction (on time) were excluded from analysis (0.96% of all trials). For all response time analyses, error trials were excluded (1.18%). For the analyses of the influence of the previous trials all trials without previous trials (first trials and trials after breaks) were excluded (1.68%).

Data Analyses

First we present the analysis concerning the two single expectations conditions, checking whether we replicate the stronger RT mismatch effect found in previous studies for predictions as compared to cues. Then we present the analyses of the double expectation conditions. While these can show how prediction and cue effects interact, a comparison of the mismatch effects from the single expectation conditions to the double expectation conditions can give further insight into whether the effects of cues and predictions are (over)additive. These analyses are presented in the third section. Afterwards we present analyses on the influence of expectation (mis)matches in the previous trial on the mismatch effect of cues and predictions in the current trial. This allows gauging whether participants flexibly adapt to expectation (not) being met in the last trial. This adaptation might either be specific to the type of expectation or could exert a general influence on either kind of expectation in the next trial.

When comparing the double expectation conditions there are several possibilities how to analyze the expectation effects. For most analyses we looked at prediction (mis)matches and cue mis(matches) as separate factors with two possible levels (match or mismatch) and checked if these factors interact. Please note that analyzing expectations as one factor with four levels - both cue and prediction mismatch, cue match/prediction mismatch, cue mismatch/prediction match, both match – leads to similar results for the presented analyses.

Single Expectation Conditions

Analysis of the single expectation conditions replicated earlier work with respect to the larger mismatch effect for self-generated predictions compared to cues. In both single expectation conditions, match trials were faster than mismatch trials. In the cue condition this difference ($M\Delta$ = 35.94ms) of match trials (M = 566.86ms) to mismatch trials (M = 602.8ms) was much smaller than for the prediction condition ($M\,\Delta$ = 122.52ms) with M = 479.38ms for match trials and M = 601.9ms for mismatch trials. The results can be seen in Figure 2. A repeated measures ANOVA on RT with type of expectation condition (cue vs. self-generated prediction) and match as repeated factors showed a main effect of match, $F(1, 22) = 88.99$, $p < .001$, $\eta_p^2 = .80$, a main effect of expectation condition with overall faster responses in self-generated prediction compared to cue trials , $F(1, 22) = 5.95$, $p = .023$, $\eta_p^2 = .21$, and an interaction of type of expectation condition and match, $F(1, 22) = 68.14$, $p < .001$, $\eta_p^2 = .76$.

The error rates only showed an overall mismatch effect[4] with an average of 1.5% errors in mismatch trials and 0.4% errors in match trials. The repeated measures ANOVA showed a

[4] Effects of expectations, i.e. the mismatch effect, exist in behavioral measurements for both response times as well as error rates. For matches, response times are usually faster than for mismatch trials. Participants usually make more errors in mismatch trials than in match trials. Thus a lower error rate usually goes hand in hand with faster response times. In the current study we restrict us to report the response time results due to the already large amount of analyses and because error rates were generally very low. While we found an overall mismatch

main effect of match, $F(1, 22) = 21.88$, $p < .001$, $\eta_p^2 = .50$, but no main effect of type of expectation condition, $F(1,22) < 1$, nor an interaction of type of expectation condition and match, $F(1, 22) = 3.68$, p=.068 , $\eta_p^2 = .14$.

Figure 2.

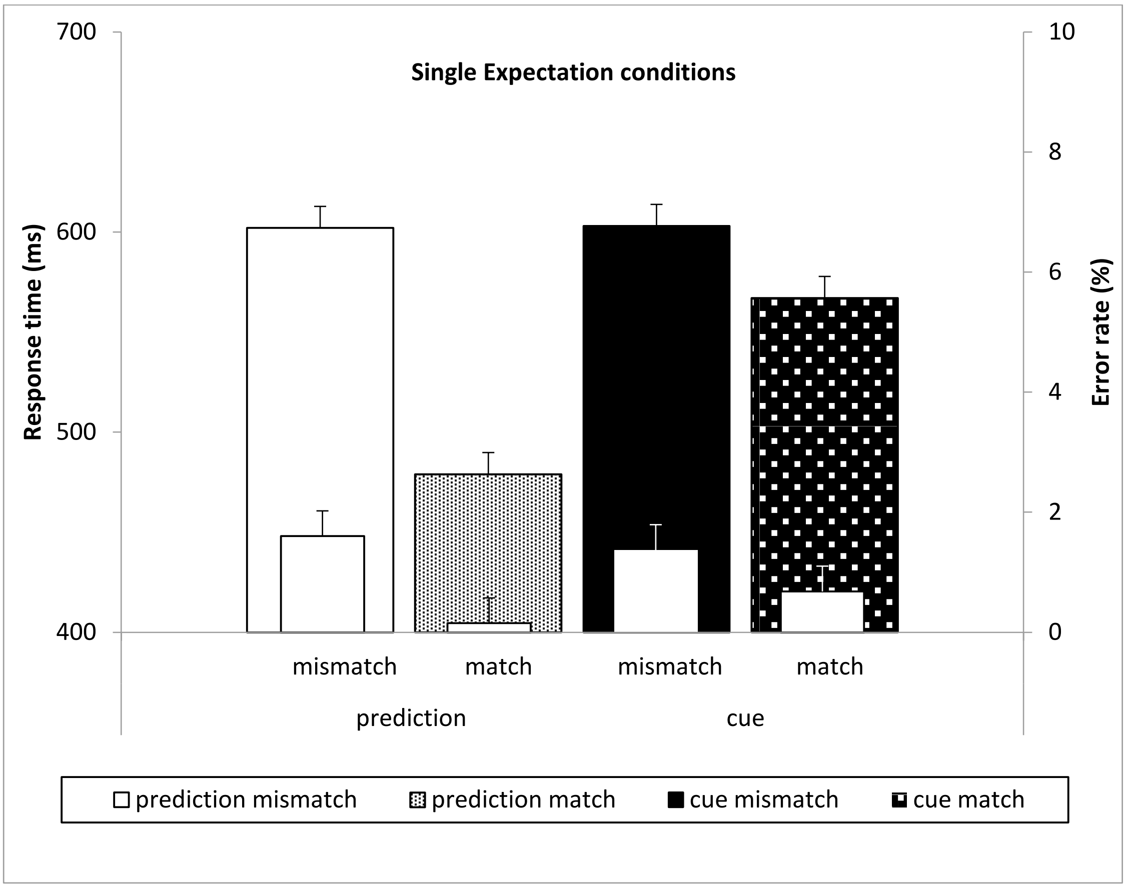

Figure 2 shows the mismatch effects for the two single expectation conditions. The larger outer bars represent the response time results, with the scale on the left side indicating the response time in milliseconds. The smaller inner bars indicate the error rates with the scale on the right side showing the error rate in %. The error bars represent the confidence interval (95%) for the interaction of type of expectation condition (cue vs. self-generated prediction) and match for repeated-measures designs according to Loftus and Masson (1994) and Jarmasz and Hollands (2009). The two bars on the left show the results for the prediction only condition: the slower mismatch trials (white outer bar) vs. faster match trials (light grey bar). The two bars on the right show

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effect also for error rates, the low amount of errors did not allow for an analysis of the more complex interactions we report for the response times. However, we show the mean error rates in the figures, so a visual comparison to the response time bars shows that the response time effects are not due to speed-accuracy trade-off for any of the investigated effects/interactions.

the results for the cue only condition: the slower mismatch trials (black bar) vs. faster match trials (dark grey bar).

Double Expectation Conditions

The results for the double expectation conditions are visualized in Figure 3a and b. Overall responses were faster in the cue-first-then-prediction condition (*M* = 512.2ms, Figure 3a) than in the prediction-first-then-cue condition (*M* = 545.4ms, Figure 3b). For both cues ($M\Delta$ =39.3ms) and predictions ($M\Delta$ =83.4ms) an overall mismatch effect could be found. The prediction mismatch effect was larger in the cue-first-then-prediction condition ($M\Delta$ = 114.1ms) than in the prediction-first-then-cue condition ($M\Delta$ = 51.2ms), while the cue mismatch effect was slightly larger in the prediction-first-then-cue condition ($M\Delta$ = 44.2ms) than in the cue-first-then-prediction condition ($M\Delta$ = 34.4ms). Expectation condition, cue match level and prediction match level show a three-way interaction which is especially evident in the prediction match/cue mismatch trials (black bars in Figure 3). While prediction matches (with mismatching cue) are as fast (*M* = 450.9ms) as double matches if the cue is presented before the prediction, prediction matches are slower (*M* = 538.2ms) than double matches if the diverging cue is presented after the prediction.

A repeated measures ANOVA on RT with expectation condition (cue-first-then-prediction vs. prediction-first-then-cue), cue match (cue match vs. cue mismatch) and prediction match (prediction match vs. prediction mismatch) as repeated factors showed a main effect of expectation condition, $F(1, 22) = 18.52$, $p < .001$, $\eta_p^2 = .46$, a main effect of cue match, $F(1, 22) = 129.88$, $p < .001$, $\eta_p^2 = .85$, and a main effect of prediction match, $F(1, 22) = 98.57$, $p < .001$, $\eta_p^2 = .81$. Furthermore, there was an interaction of expectation condition and prediction match, $F(1, 22) = 128.62$, $p < .001$, $\eta_p^2 = .85$, an interaction of expectation condition and cue match, $F(1, 22) = 20.76$, $p < .001$, $\eta_p^2 = .49$, and a three-way interaction of expectation condition, prediction match and cue match, $F(1, 22) = 18.46$, $p < .001$, $\eta_p^2 = .46$. There was no interaction of prediction match and cue match, $F(1, 22) = 3.64$, $p = .07$.

In summary if both types of expectations (cue-induced and predictions) are measured within the same trial, they both lead to mismatch effects, but the size of these effects is influenced by the order of the expectations. Prediction only matches, as well as double matches, lead to much faster RTs if the prediction is verbalized after the cue. While cue only matches are stable, irrespective of expectation order, prediction only matches are relatively slower when the prediction is verbalized before the cue. This also holds true for double matches even though the cue "affirms" the prediction in these trials.

Figure 3a.

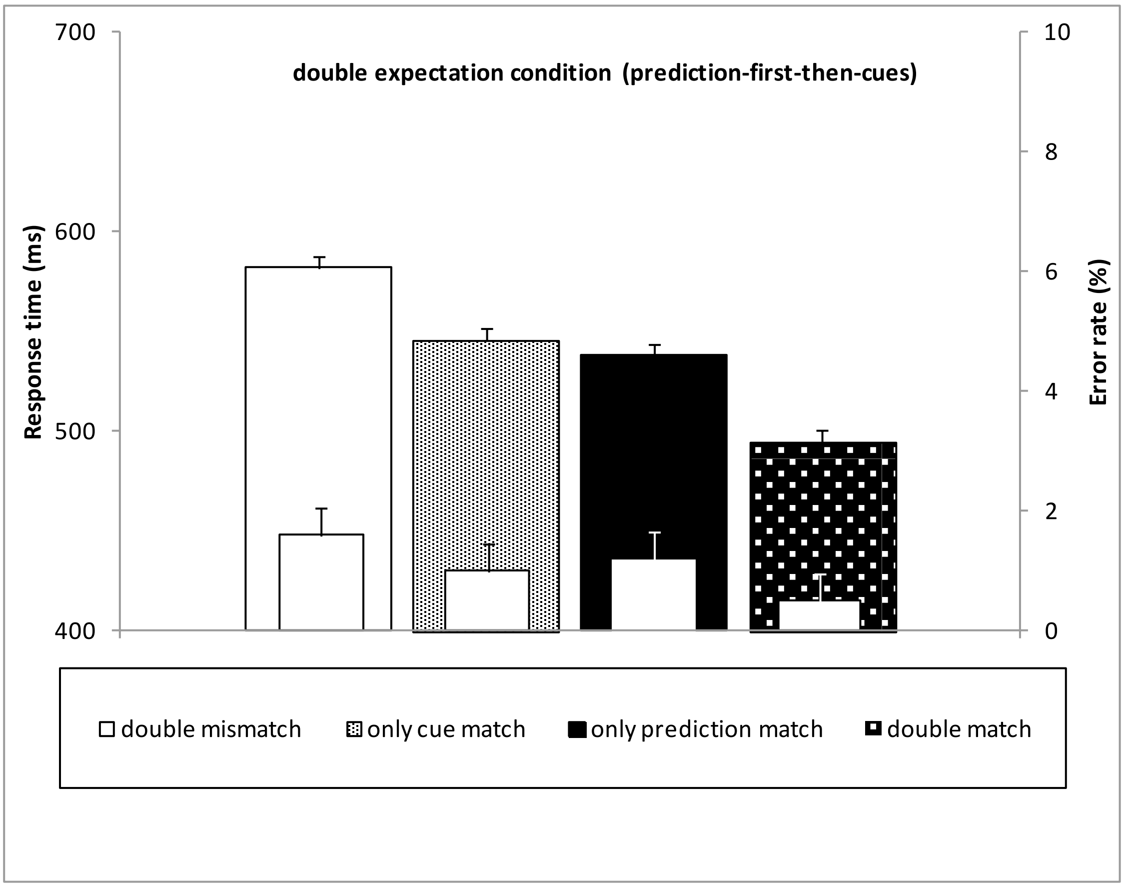

Figure 3b.

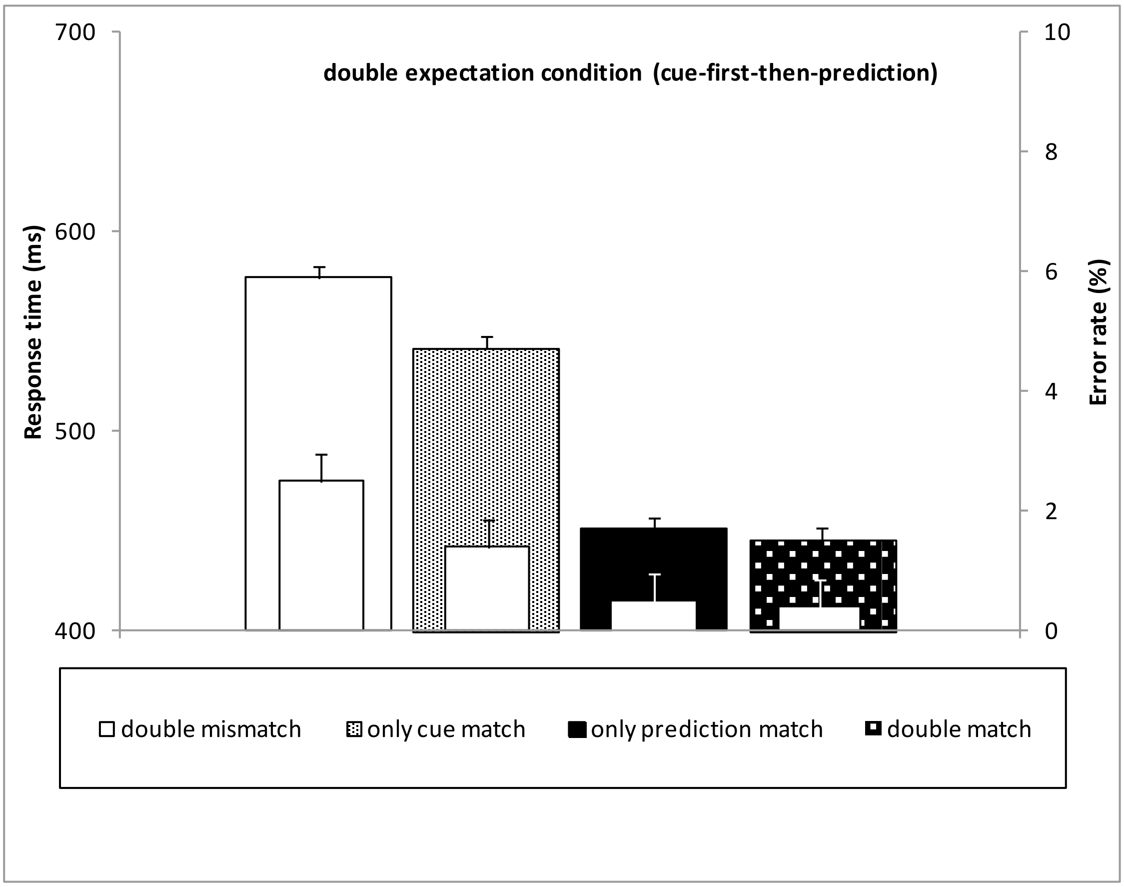

Figure 3 shows the mismatch effects for the two double expectation conditions. Figure 3a shows the results for the prediction-first-then-cue condition. Figure 3b shows the results for the cue-first-then-prediction condition. The larger outer bars represent the response time results, with the scale on the left side indicating the response time in milliseconds. The smaller inner bars (white) indicate the error rates with the scale on the right side showing the error rate in %. The error bars represent the confidence interval (95%) for the three-way interaction of expectation condition (cue-first-then-prediction vs. prediction-first-than-cue), cue match (cue match vs. cue mismatch) and prediction match (prediction match vs. prediction mismatch) for repeated-measures designs according to Loftus and Masson(1994) and Jarmasz and Hollands (2009). In both figures the outer left bars (white) show the results for double mismatches i.e. trials in which both prediction and cue did not match the stimulus. The inner left bars (light grey) show the results for cue matches i.e. trials in which the cue matches the stimulus while the prediction did not match the stimulus. The inner right bars (black) show the results for prediction matches i.e. the prediction matches the stimulus but the cue did not match the stimulus. The outer right bars (dark grey) show the results for double matches i.e. trials in which prediction and cue are the same and both match the stimulus. The black bar in Figure 3b would be the results for the type of trial whose setup has been exemplarily shown in Figure1 on the right side.

Two vs. One Expectation

Next we tested whether the presence of a second type of expectation (that sometimes pointed towards a different stimulus) added to the single expectation effect of either cue or prediction. While the previous analyses could give insight into how match and mismatch of both types of expectations interact, only a comparison of single expectation condition to double expectation condition can show whether the second expectation shows (over)additive effects compared to one expectation alone. The RT mismatch effects for the comparisons of the different expectation conditions can be found in Table 1.

First we analyzed the *cue mismatch effect*. A repeated measures ANOVA on RT with expectation condition (single cue vs. cue-first-then-prediction vs. prediction-first-than-cue) and match (cue match vs. cue mismatch) as repeated factors showed a main effect of match with slower responses for mismatch trials (M = 554.5ms) than for match trials (M = 515.8ms), $F(1, 22) = 75.03$, $p < .001$, $\eta_p^2 = .77$, a main effect of condition, with slower responses in the single cue (M = 586.3ms) vs. prediction first then cue (M = 545.4ms) and cue first then prediction (M = 512.2 ms) conditions, $F(2, 44) = 17.59$, $p < .001$, $\eta_p^2 = .44$. Given the lack of an interaction of expectation condition and match, $F(2, 44) < 1$, this analysis pointed towards RT differences among expectation conditions that exist additionally to (mis)match effects.

As an additional analysis we specifically examined those trials where the predicted stimulus differed from the cued stimulus. T-tests showed that the mismatch effect for cues did not significantly differ between the blocks only containing cues vs. blocks containing cues and predictions. The cue mismatch effect in the cue only condition (mean difference of cue mismatch and match trials) did not differ significantly from the cue mismatch effect if a diverging prediction was made (mean difference of double mismatch and cue match but prediction mismatch trials) in either the cue first then prediction condition, $t(22) < 0.16$, or the prediction first then cue condition, $t(22) < 0.31$. In summary the effect of the cue-induced expectation on response time was not influenced by an additional self-generated expectation, irrespective of whether this expectation was verbalized before or after cue presentation and irrespective of whether it was congruent with the cue or not.

In contrast the prediction mismatch effect was influenced by the presentation of the cue. A repeated measures ANOVA on RT with expectation condition (singe prediction vs. cue-first-then-prediction vs. prediction-first-then-cue) and match (prediction match vs. prediction mismatch) as repeated factors showed a main effect of match, $F(1, 22) = 117.01$, $p < .001$, $\eta_p^2 = .84$, and a main effect of expectation condition, $F(2, 44) = 8.18$, $p = .001$, $\eta_p^2 = .27$. Furthermore, there was an interaction of expectation condition and match, $F(2, 44) = 71.99$, $p < .001$, $\eta_p^2 = .76$. In the single prediction condition, match trials ($M = 479.39$ms) were on average 122.51ms faster than mismatch trials ($M = 601.9$ms). Similarly, if a cue was presented before the prediction prompt, prediction match trials ($M = 448.36$ms) were on average 114.09ms faster than mismatch trials ($M = 562.54$ms). Yet, if a cue was presented after the prediction, prediction match trials ($M = 515.77$ms) were only 51.2ms faster than mismatch trials ($M = 566.97$ms).

The main effects for expectation condition in both analyses (cue and prediction) were due to the response times being overall longer for the single expectation conditions than in the double expectation conditions.[5] Due to these general differences between the single and the double blocks, simply comparing (double) match trials did not seem a warranted strategy to check for (over)additive effects of the two types of expectations. If there was no overall expectation condition effect and the double match trials in a double expectation condition were faster than the match trials in a single expectation condition one could infer an additive effect. However due to the double expectation condition trials being overall faster (also for

[5] We cannot say for certain why this is the case. It is possible that combining two types of expectations leads to faster RTs overall, either due to expectations themselves or due to mediating factors. For example participants might concentrate more on the task if they have to distinguish between two expectations. However we speculate that one contributing factor to this difference could be the temporal setup of the experiment we used. In the single expectation conditions the time between expectation prompt and stimulus was relatively long.

mismatch trials) this comparison does not give clear results. Thus in order to see whether cue effects can add onto prediction effects we compared the mismatch effects i.e. differences between conditions.

T-tests revealed that there was no significant difference between the mismatch effects of the single prediction condition and the cue-first–then-prediction condition $t(22) < 0.78$, while the prediction mismatch effect differed between the prediction-first-then-cue condition and the single prediction condition, as well as the prediction-first-then-cue condition and the cue-first-then-prediction condition (both $t(22) > 10.43$, $p < 0.001$). A *t*-test revealed that the mismatch effect between the single prediction condition (difference between prediction match and prediction mismatch trials) and the maximum mismatch effect in the cue-first–then-prediction condition (i.e. the difference between the double matches and double mismatches) did not differ significantly $t(22) < 1.58$[6].

A *t*-test revealed that the response time for double matches in the cue-first–then-prediction condition was not significantly shorter than the prediction match (cue mismatch) trials $t(22) < 0.63$. The mismatch effect (difference of prediction matching or mismatching the stimulus) in the prediction only condition was as large as the largest difference between double mismatches (both cue and predictions did not match the stimulus) and double matches (both cue and prediction matched the stimulus) in the double expectation conditions.

Taken together these analyses indicate that double matches did not lead to RT advantages compared to prediction only matches – cue-induced expectations and predictions showed no additive effects and predictions lead to the strongest expectations effects we could find.

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[6] To allow for this specific analysis we defined the expectations in the double expectation conditions as one factor with four levels - both cue and predictions mismatch, cue match/prediction mismatch, cue mismatch/prediction match and both match - from which we chose the relevant pair to compare to the single prediction condition.

Table 1: Cue effects and prediction effects in ms

Cue effect comparison between single cue condition and double expectation conditions.			Prediction effect comparison between single prediction condition and double expectation conditions.		
single cue condition	cue mismatch	602.8	single prediction condition	prediction mismatch	601.9
	cue match	566.9		prediction match	479.39
	difference (cue mismatch effect)	35.9		(prediction mismatch effect)	122.51
cue first then prediciton condition	cue mismatch	527.9	cue first then prediciton condition	prediction mismatch	562.54
	cue match	493.5		prediction match	448.39
	difference (cue mismatch effect)	34.4		(prediction mismatch effect)	114.09
prediciton first then cue condition	cue mismatch	565.6	prediciton first then cue condition	prediction mismatch	566.97
	cue match	521.4		prediction match	515.77
	difference (cue mismatch effect)	44.2		(prediction mismatch effect)	51.2

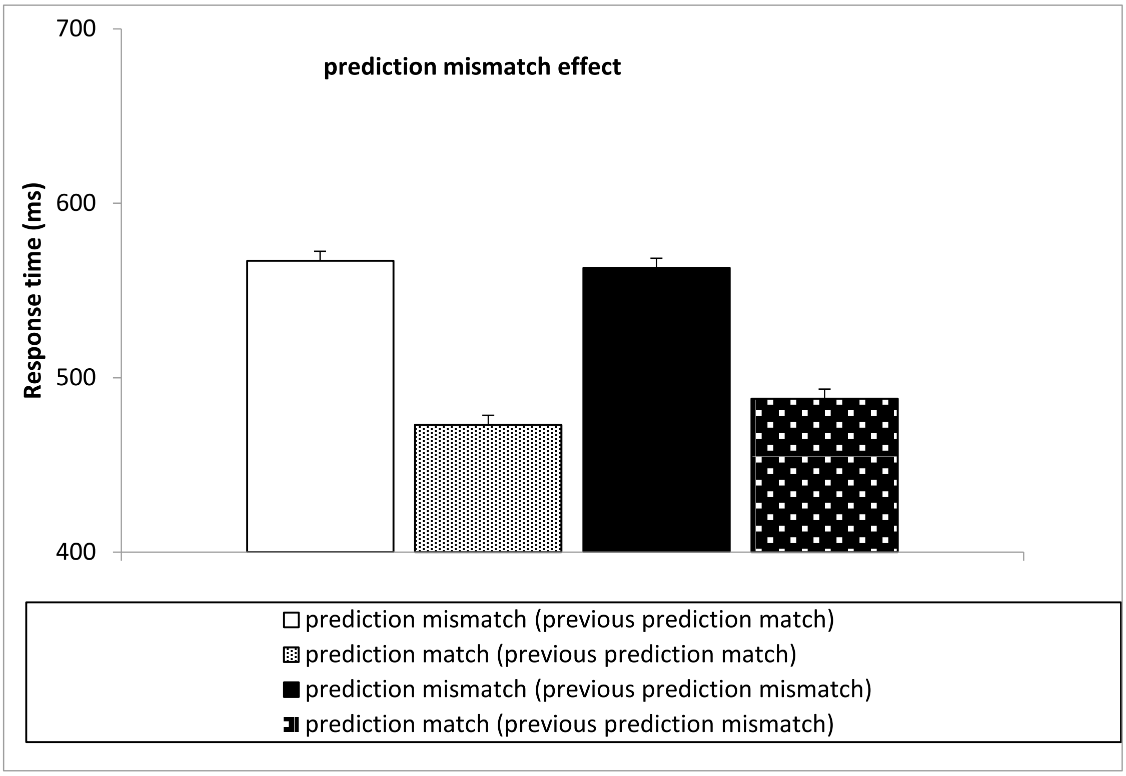
Influence of Match in Previous Trial

Additional evidence on whether or not cue-based and self-generated expectations overlap, we investigated how expectation effects were influenced by a (mis)match of the expectation of either kind in the previous trial. For the double expectation conditions, the prediction mismatch effect was 94.2ms if the prediction in the previous trial matched the stimulus but only 74.8ms if the prediction in the previous trial did not match the stimulus. This difference between the prediction mismatch effect depending on the previous prediction (mis)match was similar whether the prediction was presented before the cue ($M\Delta$ = 17.0ms) or after the cue ($M\Delta$ = 18.9ms). The mismatch effect for cues was very similar whether the cue in the previous trial matched ($M\Delta$ = 38.7ms) or did not match ($M\Delta$ = 40ms). No cross-effects between expectations types were found: Whether one type of expectation matched in the previous trial or not did not influence the mismatch effect of the other expectation in the current trial. The prediction mismatch effect was not influenced by whether the cue matched in the previous trial (*MΔ* = 82.6ms) or not (*MΔ* = 83.4ms) and the cue mismatch effect was not influenced by whether the prediction matched in the previous trial (*MΔ* = 40.1ms) or not (*MΔ* = 38.9ms).

A repeated measures ANOVA on RT for the double expectation conditions with expectation condition (cue-first-then-prediction vs. prediction-first-than-cue), cue match (cue match vs. cue mismatch), prediction match (prediction match vs. prediction mismatch), previous cue match (cue match vs. cue mismatch in the previous trials) and previous prediction match (prediction match vs. prediction mismatch during the previous trial) as repeated factors showed no interaction of cue match and previous cue match $F(1, 22) < 1$, but an interaction of prediction match and previous prediction match $F(1, 22) = 10.69$, $p = .004$, $\eta_p^2 = .33$. There was no interaction of expectation condition, prediction match and previous prediction match $F(1, 22) < 1$. For all other results of main effects or interactions of this analysis please see Table 2 in the Appendix (as all significant main effects/interactions correspond to analyses previously reported , with the exception of the unexpected five-way interaction).

The results show that predictions have a stronger mismatch effect, i.e. are relied on more, if the prediction in the previous trial matched. In contrast cue effects were not influenced by whether the cue of the previous trial matched. Both expectation formats were not influenced by the previous match of the respective other expectation (format). Thus, the different forms of expectation did not overlap in the adaptation to mismatches.

Figure 4.



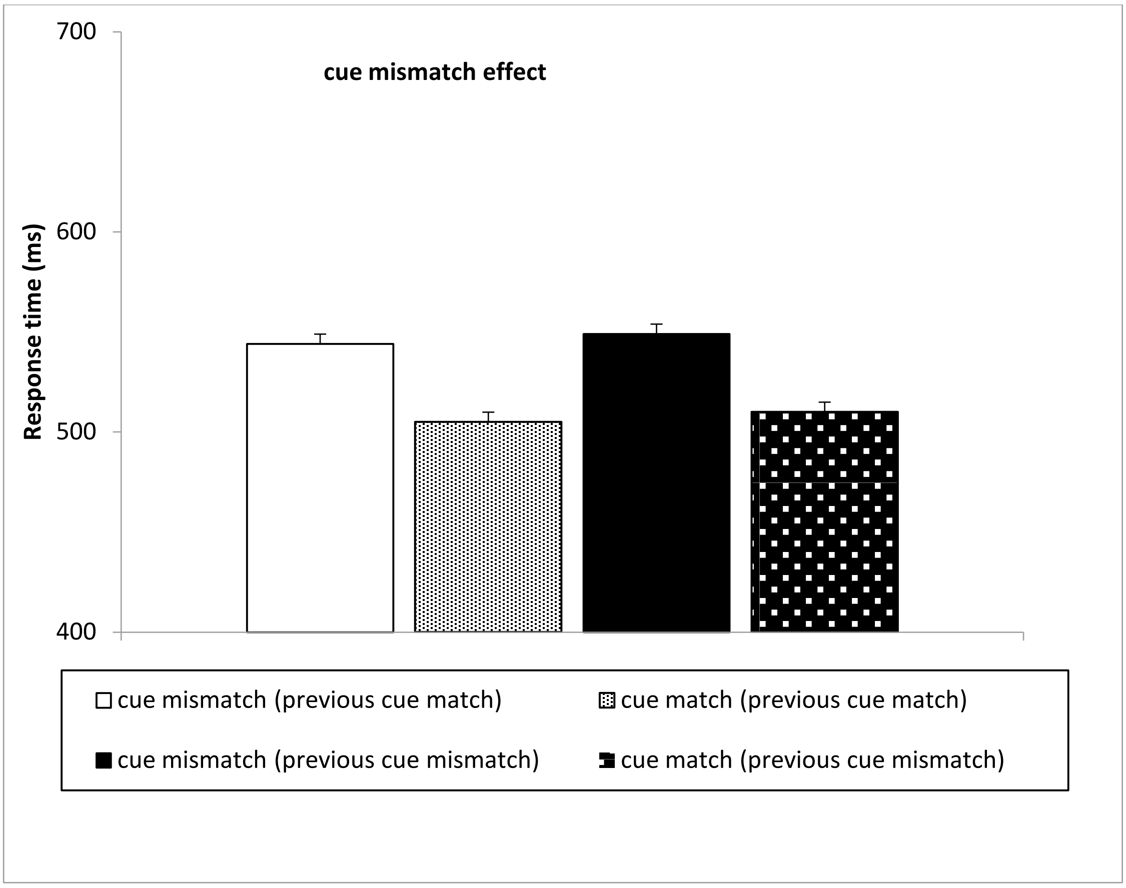


Figure 4 shows the mismatch effect on response time (averaged over both double expectation conditions) in relation to whether the expectation matched in the previous trial. The error bars represent the confidence interval

(95%) for the interaction of match and previous match (prediction match x previous prediction match for 4a and cue match x previous cue match for 4b) for repeated-measures designs according to Loftus and Masson (1994) and Jarmasz and Hollands (2009).

Figure 4a shows the response times results if the prediction matched (light and dark grey bar) or mismatched (black and white bar) the stimulus in the current trial (irrespective of whether the cue matched the stimulus) depending on whether the prediction in the preceding trial matched the stimulus in the preceding trial (white and light grey bars on the left) or the prediction mismatched the stimulus in the preceding trial (black and dark grey bars on the right).

Figure 4b shows the response time results if the cue matched (light and dark grey bar) or mismatched (black and white bar) the stimulus in the current trial (irrespective of whether the prediction matched the stimulus) depending on whether the cue in the preceding trial matched the stimulus in the preceding trial (white and light grey bars on the left) or the cue mismatched the stimulus in the preceding trial (black and dark grey bars on the right).

Predictions and Stimulus Frequency

We compared the frequency with which participants predicted the different stimuli to the frequency with which the stimuli occurred to check whether participants really verbalized predictions and not just guessed stimuli entirely at random. In addition we checked whether predictions differed depending on whether the participants verbalized them before or after cue presentation to see whether they were strongly influenced in their own predictions by the cues.

Overall participants predicted the 60% stimulus in 53.39% of trials, the 30% stimulus in 33.96% of trials and the 10% stimulus in 12.67% of trials. This shows that participants did not just verbalize arbitrarily but showed probability matching. The similar frequencies also prevented a potential confound with respect to the amount of (mis)matches compared to the respective cue conditions (cues were shown in the same frequency as the stimuli). The order of the two expectation formats influenced predictions only slightly: In the prediction-first-then-cue double expectation condition the two expectations were congruent in 43.19% of trials. When the cue was presented first, the expectations were congruent in 44.89% of trials. Thus participants predicted the stimulus which the cue indicated only 1.7% more often if they had seen the cue before forming their prediction. Predictions were not strongly influenced by the preceding cue.

Discussion

We compared the influence of self-generated expectations (predictions) and cue-induced expectations on the RT mismatch effect in a stimulus response time task. We used different expectation conditions to allow a comparison of the exclusive influence of each type of expectation as well as two conditions in which both forms of expectations were combined (in either order). This allowed assessing the strength as well as interactions of expectation (mis)match effects. While earlier studies have found a stronger influence of predictions on performance compared to cues (for the first comparison see: Acosta, 1982; for a review see: Gaschler et al., 2014), all of these studies have measured predictions and cue-induced expectations in separate trials (blocks). We could replicate these findings for our single expectation conditions. In addition we could show that predictions also show a stronger effect when diverging cues have been shown within the same trial.

The mismatch effect of predictions was the strongest expectation effect that we could find and it could not be additionally enhanced by cues. Yet, the effect of cues could not be enhanced by predictions either. While the mismatch effect for cues was smaller than the one for predictions, it was not erased by the effect of predictions. The expectation effects were not cumulative. This could be explained in two different ways: Either the underlying process is the same for both types of expectations. As the effect elicited by predictions is already at ceiling, an additional cue which does tap into the same process cannot add to the RT effect. However, this explanation is not in line with the finding that cue effects were not overshadowed by prediction effects. Thus, assuming that cue-induced vs. self-generated expectations differ qualitatively rather than quantitatively seems to better explain the results.

Our results suggest that cue-based and self-generated expectations influenced performance at different magnitude and in different ways. The fastest responses we found were the prediction only matches as well as the double matches in the condition where the participants were first cued and then generated their own predictions (and both matched the stimulus actually appearing). The mismatch effect in the prediction only condition was as large as the largest mismatch effect in the double expectation conditions (i.e. the difference between double mismatches and double matches in the cue-first-then-prediction-condition). In this double expectation condition the prediction only match trials were as fast as the double match trials. While the prediction only match was slower than the double matches in the prediction-first-then-cue condition, this effect was not due to an addition of cue match and prediction match effect but rather due to slower prediction only matches. The double matches in this condition were slower than the double matches in the other double expectation condition. Also the difference between double mismatches and double matches was smaller in this than in the other double expectation condition (and than the prediction mismatch effect in the prediction only condition). This indicates that whilst cue and prediction effects do not add up, the effect of predictions can be diminished by a subsequent cue.

The results relate to the idea that internally triggered and externally triggered expectations lead to different types of action modes (e.g.: Herwig & Waszak, 2009, 2012 ; Obhi, & Haggard, 2004; Pfister, Kiesel, and Melcher, 2010). If an internally triggered expectation (prediction) is disturbed by an externally triggered expectation (cue), expectation effects decrease. This is similar to the “truncation” condition in Obhi and Haggard (2004) where subjects were forced to switch from an internally generated action mode to an externally triggered mode. A cue, even if it affirms the prediction, diminishes the expectation effect when presented after the verbalization of the prediction. Thus double matches are slower when the cue is presented after the prediction. If cue and prediction contradict each other both modes are activated and if one of the expectations matches the stimulus a mismatch effect can still be found (both cue only matches and prediction only matches are faster than double mismatches). However, when the prediction is verbalized after the cue presentation, the internally triggered mode is undisturbed by the cue and the prediction effect is as large as without an additional cue.

The larger effect of predictions is in accordance with the hypothesis that the object of predictions (i.e. the predicted stimulus) is represented in the focus of attention in working memory (e.g. Oberauer et al., 2013). According to Gaschler et al. (2014) the demand to verbalize a prediction might single out the stimulus representation which had been leading in activation just by a small margin at the beginning of the trial. Schwager et al. (2017) suggested that the demand to verbalize a prediction leads to this privileged representation in the focus of attention in working memory even under adverse circumstances (lack of validity and lack of response-relevance). The privileged representation leads to large behavioral effects. In contrast cues, especially if they are of relatively low validity/importance (as they are in the current experiment) might not lead to representing the corresponding stimulus in the focus of attention in working memory. Cues might also be represented in working memory, yet outside the focus (unless they are of very high validity/importance that leads to a heightened attendance for the cues). Thus, cues might exert priming effects independently of the prediction as they use different representations.

The perspective that generating and verbalizing a prediction has a strong impact on representations and performance is in line with early work by Hacker and Hinrichs (1979). They found that mismatch effects could not only be induced by predictions, but also by "non-predictions". If participants were asked to verbalize which stimulus they expected least to occur on the next trial, they responded faster if the verbalized stimulus was presented, compared to other stimuli – even though the stimulus was explicitly expected not to occur.

This seems to imply that the activation of (stimulus) representations due to self-generating expectations is sufficient to influence responses even if the expectation is that the represented stimulus will not occur.

One aspect relevant for the validity of the prediction task has to be highlighted. In the current study participants formed their predictions in accordance with the probability the respective stimulus occurred, slightly overestimating infrequent and underestimating frequent stimuli. This is in accordance with other studies that found probability matching for expectations (e.g. James & Koehler, 2011; Gaissmaier & Schooler, 2008). Participants did not just say random words but rather matched their predictions to their prior experiences of stimulus probability. As an additional manipulation check we compared how often participants matched their predictions to the cues. While participants predicted the same stimulus as the cue had indicated slightly more often if they had seen the cue before verbalizing their prediction the two double expectation conditions were generally very similar concerning the predictions. The results suggest that participants were overall able to formulate predictions independently of the cues, allowing for a fair comparison of cue and prediction effects.

We have to keep in mind that verbalized predictions are a snapshot. Potentially predictions changed (on some trials) between verbalization and stimulus onset. In the condition where the cue was presented after the verbalization of the prediction there was more time for such a change to occur. This might explain the weaker behavioral effects of the prediction matches in this condition. Cues, in turn, show a smaller effect than self-generated expectations and it is questionable whether they really induce expectations (to the same extent and on every trial) in the way that letting participants form their own expectations does. This implies that when researching expectations (and their impact on certain behavior or psychological processes) measuring predictions is usually the more appropriate operationalization of expectations instead of just showing cues to the participants. However, sometimes the stronger experimental control of cues is necessary for the experimental setup. Only cues can be manipulated for every trial (instead of only measuring the prediction) and thus allow for example for certain sequences of cues and their influence in a row of consecutive trials. Cues may also be used without verbalization which might be necessary in some experimental setups where speech production hampers the measurement of other physiological measurements like EEG. For these types of experiments that rely on the higher experimental control of cues it is usually not measured whether participants formulate converging predictions or really expect what the cue indicates and whether these possible diverging predictions might influence the experimental outcome. Our results imply that even for those trials where participants formulate diverging predictions the cues still show a stable effect and can thus be used effectively. However, results from studies that used cues should not be generalized to represent (self-generated) expectations but rather be interpreted as a form of (automatic) priming effects.

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Appendices

Table 2. ANOVA on RT for the double expectation conditions with expectation condition (cue-first-then-prediction vs. prediction-first-than-cue), cue match (cue match vs. cue mismatch), prediction match (prediction match vs. prediction mismatch), previous cue match (cue match vs. cue mismatch in the previous trials) and previous prediction match (prediction match vs. prediction mismatch during the previous trial) as repeated factors.

Factors	df	F	p	η_p^2
expectation condition (prediction before cue vs. cue before prediction)	1 , 22	18.01	< .001	.450
cue match level	1 , 22	99.41	< .001	.819
prediction match level	1 , 22	103.69	< .001	.825
previous cue match level	1 , 22	3.06	.094	.122
previsous prediction match level	1 , 22	3.18	.088	.126
expectation condition* cue match level	1 , 22	15.76	.001	.417
expectation condition* prediction match level	1 , 22	117.59	< .001	.842
cue match level * prediction match level	1 , 22	2.69	.115	.109
expectation condition* cue match level * prediction match level	1 , 22	12.80	.002	.368
expectation condition* previous cue match level	1 , 22	0.90	.352	.040
cue match level * previous cue match level	1 , 22	0.25	.625	.011
expectation condition* cue match level * previous cue match level	1 , 22	1.02	.325	.044
prediction match level * previous cue match level	1 , 22	0.07	.800	.003
expectation condition* prediction match level * previous cue match level	1 , 22	0.18	.675	.008
cue match level * prediction match level * previous cue match level	1 , 22	2.19	.153	.091
expectation condition* cue match level * prediction match level * previous cue match level	1 , 22	0.59	.451	.026
expectation condition* previous prediction match level	1 , 22	0.20	.662	.009
cue match level * previous prediction match level	1 , 22	< 0.01	.946	< .001
expectation condition* cue match level * previous prediction match level	1 , 22	1.66	.211	.070
prediction match level * previous prediction match level	1 , 22	10.69	.004	.327
expectation condition* prediction match level * previous prediction match level	1 , 22	0.40	.532	.018
cue match level * prediction match level * previous prediction match level	1 , 22	0.19	.667	.009
expectation condition* cue match level * prediction match level * previous prediction match level	1 , 22	0.10	.756	.004
previous cue match * previous prediction match	1 , 22	0.36	.556	.016
expectation condition* previous cue match level * previous prediction match level	1 , 22	0.01	.924	< .001
cue match level * previous cue match level * previous prediction match level	1 , 22	0.09	.765	.004
expectation condition* cue match level * previous cue match level * previous prediction match level	1 , 22	< 0.01	.993	< .001
prediction match level * previous cue match level * previous prediction match level	1 , 22	1.35	.258	.058
expectation condition* prediction match level * previous cue match level * previous prediction match level	1 , 22	0.50	.487	.022
cue match level * prediction match level * previous cue match level * previous prediction match level	1 , 22	1.01	.327	.044
expectation condition* cue match level * prediction match level * previous cue match level * previous prediction match level	1 , 22	4.45	.047	.168

Pilot study

The methods of the pilot study were similar to our main experiment except that it was tested in a single session at the FernUniversität Hagen and we only used three types of expectation conditions: a cue only condition, a prediction only condition and a double expectation condition where we first let participants verbalize predictions and then presented a cue.

Twenty-three participants took part in this experiment. When only looking at the single expectation conditions, the mismatch effect in the cue only condition (34ms RT difference between cue match and cue mismatch trials) was smaller than the mismatch effect in the prediction only condition (76ms). A repeated measures ANOVA on RT with type of expectation condition (cue vs. prediction) and match as repeated factors showed a main effect of match, $F(1, 22) = 32.65$, $p < .001$, $\eta_p^2 = .60$, and an interaction of type of expectation condition and match, $F(1, 22) = 4.89$, $p = .038$, $\eta_p^2 = .18$, but no main effect of condition, $F(1, 22) = 3.28$, $p = .08$.

When comparing the cue mismatch effect of the cue only condition to the cue mismatch effect of the prediction-first-then-cue condition (42ms) we found that the influence of the cue did not differ significantly whether it was preceded by a prediction or not. A repeated measures ANOVA on RT with type of expectation condition (cue only vs. prediction then cue) and cue match as repeated factors showed a main effect of match, $F(1, 22) = 21.11$, $p < .001$, $\eta_p^2 = .49$, but no main effect of condition, $F(1, 22) = 3.40$, $p = .08$, nor an interaction of type of expectation condition and cue match, $F(1, 22) = 0.30$.

When comparing the prediction mismatch effect of the prediction only condition to the prediction mismatch effect (28ms) of the prediction-first-then-cue condition we found that the influence of the prediction decreased if the prediction was followed by a (possibly diverging) cue. A repeated measures ANOVA on RT with type of expectation condition (prediction only vs. prediction-first-then-cue) and prediction match as repeated factors showed a main effect of prediction match, $F(1, 22) = 14.78$, $p = .001$, $\eta_p^2 = .40$, and an interaction of type of expectation condition and prediction match, $F(1, 22) = 25.40$, $p < .001$, $\eta_p^2 = .54$, but no main effect of condition, $F(1, 22) < .01$.

This decrease of the prediction mismatch effect in the double expectation condition led to a comparable impact of cues and prediction in the double expectation condition. A *t*-test on the respective mismatch effects (average difference between cue mismatch and cue match and average difference between prediction mismatch and match) revealed that there was no significantly different mismatch effect between the cues and predictions in the double expectation (prediction-first-then-cue) condition, $t(22) < 1.15$.

Please note that a direct comparison of the single expectation conditions to the double expectation conditions is not methodologically sound because any effects we could (not) find could either be due to the second expectation being prompted, the order of the expectations, and/or temporal differences in the trial setup. For this reason we used two double expectation conditions in our main experiment, one starting with the cue and one with the prediction. Furthermore, the expectation prompts for the first expectation in the double expectation conditions had the same temporal distance to the stimulus as the expectation prompts in the single expectation conditions.

In addition the pilot study was putting these methods of measuring expectations to a test. The experiment was very long and exhausting with a duration of more than 1.5 hours. Due to this we decided two divide our main experiments into two parts.