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Methodological considerations for the study of non-conscious processes through the masked priming paradigm

Consideraciones metodológicas para el estudio de los procesos no conscientes a través del paradigma del priming enmascarado

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INFORMACION

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ABSTRACT

Unconscious processes can be experimentally studied from a great variety of paradigms. One of the most widely used is the so-called “masked priming” in which a stimulus (i.e., a word) called prime is masked in such a way that it cannot be consciously perceived but still influences the response to another subsequent stimulus called target. However, because of the complexity of conscious processes, there are a number of variables that must be taken care of when applying this paradigm. Unfortunately, most of those variables are difficult to grasp and therefore it becomes a trial and error struggle for scientists attempting to scientifically study consciousness. The purpose of this paper is to make a contribution to facilitate the task for those scientists. To that extent, we will discuss about current literature of masked priming based on two main themes: The central problems that have been addressed through the use of masked priming paradigm (i.e., semantics, emotions and attention), and methodological considerations (i.e., the presentation format of the stimuli, the masks, visibility measures and the Stimulus Onset Asynchrony [SOA]). The present article might be useful for those researchers planning to utilize this paradigm to study the phenomenon of consciousness.

Palabras clave:
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RESUMEN

Los procesos inconscientes pueden estudiarse experimentalmente desde una gran variedad de paradigmas. Uno de los más utilizados es el llamado “priming enmascarado”, en el que un estímulo (es decir, una palabra) llamado principal se enmascara de tal manera que no puede ser percibido conscientemente, pero aún influye en la respuesta a otro estímulo posterior llamado objetivo. Sin embargo, debido a la complejidad de los procesos conscientes, existe una serie de variables que deben cuidarse al aplicar este paradigma. Desafortunadamente, la mayoría de esas variables son difíciles de comprender y, por lo tanto, esto se convierte en una lucha de prueba y error para los investigadores que intentan estudiar científicamente la conciencia. El propósito de este trabajo es hacer una contribución para facilitar la tarea de estos científicos. En esa medida, discutiremos la literatura actual sobre el priming enmascarado sobre la base de dos temas principales: los problemas centrales que se han abordado mediante el uso del paradigma del priming enmascarado (es decir, la semántica, las emociones y la atención) y las consideraciones metodológicas (es decir, el formato de presentación de los estímulos, las máscaras, las medidas de visibilidad y el Stimulus Onset Asynchrony [SOA]). El presente artículo puede ser de utilidad para aquellos investigadores que planeen utilizar este paradigma para estudiar el fenómeno de la conciencia.

1.Introduction

The ability to be aware of the reality around us, and reflect on our thoughts, emotions, and existence, is possible because we have consciousness. Consciousness has been addressed throughout the centuries by means of simple speculation or philosophical reflection (Andreau, 2019), however, in recent decades, consciousness started to be studied from a scientific perspective (Dehaene, 2011; Jylkkä & Railo, 2019). Although a precise definition of consciousness is still a matter of debate, in the scientific literature we find a typical differentiation between the content of consciousness and the state of consciousness (Dehaene & Changeux, 2011). The former refers to the fact of being aware of certain information in a given moment (i.e., being aware of this text) while the latter is related to the level of alertness of the person (i.e., states of coma, vegetative state, etc.; Dehaene et al., 2014). In the present article, the term “consciousness” will refer to the content of consciousness. The scientific exploration of consciousness generated several theories which attempt to define and explain its properties. Since it would exceed the goal of the present article, we will briefly mention them: The Multiple Drafts Model (Dennett, 1991), focuses on the information processing aspects of the mind; The Global Workspace Theory (Baars, 2005), posits that conscious cognitive content is readily available to perform several cognitive processes, such as attention, evaluation, memory and verbal report; The Global Neuronal Workspace Theory (Dehaene, 2011; Dehaene et al., 2006, 2011, 2014; Dehaene & Changeux, 2011; Dehaene & Naccache, 2001; Kouider & Dehaene, 2007), predicts that conscious states obey a nonlinear stimulus salience function (i.e a progressive increase in stimulus visibility should necessarily be accompanied by an abrupt transition of the neural workspace into a corresponding activity pattern); The Dynamic Core Theory (Edelman & Tononi, 2000), views the neural correlates of consciousness as functional clusters in the thalamocortical system, where neural interactions lead to differentiated, yet unitary, metastable states; The Integrated Information Theory (Oizumi et al., 2014; Tononi, 2004, 2008), argues that a physical system's consciousness is defined by its causal properties, thus being an intrinsic and key element of all physical systems; The Recurrent Thalamo-cortical Resonance Theory (Llinás et al., 1998), is a recurring phenomena of oscillatory neural activity between thalamus and various cortical brain regions. The theory proposes an integration of sensory information as the totality of brain perception; The Neural Coalition Theory (Crick & Koch, 2003), explains that the past experiences of coalitions of active neurons are likely to forecast relevant objects and events into consciousness. Said neurons form coalitions under the possible influence of biases stemming from different parts of the brain (i.e: signals informing on where they should attend to); and the different versions of Higher Order Theories (Brown et al., 2019; Lau & Rosenthal, 2011; LeDoux & Brown, 2017), which elaborate that consciousness stems from perceptions about first-order mental states. Particularly, phenomenal consciousness is considered as a high-order representation of perceptual or quasi perceptual stimuli. As we can see, the study of conscious and unconscious cognitive processes has increased over the years (Kouider & Dehaene, 2007; Van den Bussche et al., 2009). Nevertheless, the results of those studies have been the subject of debate due to their theoretical implications. For example, if one theory stated that a type of result is associated only with conscious processing and another study posits that the same type of result can occur without consciousness, then contradictory explanations would be provided from a theoretical point of view (Dehaene et al., 2014). Therefore, it is of paramount importance to clarify the methodological procedures behind the paradigms utilized to study conscious processes. One of the most widely used is the so-called "masked priming" paradigm.

1.1 The masked priming paradigm

Consciousness has been investigated under a great variety of paradigms like binocular rivalry, continuous flash suppression (Tsuchiya & Koch, 2005), inattentional blindness (Simons & Ambinder, 2005), visual crowding (Cavanagh, 2001) and degraded visual stimulation (Dixon, 1971). Nonetheless, one of the most widely used is the so-called masked priming (Dehaene, 2011). In this paradigm, a stimulus (i.e. image, word, symbol, etc.) called prime is masked so that it cannot be consciously perceived by the observers, although it still influences their response to another subsequent stimulus, called target (Dehaene, 2011). An example of this paradigm is the classical categorization task in which participants must classify a group of target words as belonging to one category (animals) or another (objects). Target stimuli are usually presented on a computer monitor one at a time, they are clearly visible and the participant must classify them as belonging to one category or another by pressing a button.

However, before the appearance of the target stimulus, a prime stimulus is presented very briefly between two other stimuli called masks whose function is to considerably decrease the visibility of the prime stimulus. For our example, the prime stimulus could be a word that is related to the aforementioned categories (i.e., the prime stimulus "dog" is related to the target stimulus "wolf" and the prime stimulus "hammer" is related to the target stimulus "nail"). Therefore, sometimes the prime and the target would correspond to the same category (congruent pairs: hammer-nail) and sometimes they belong to different categories (incongruent pairs: hammer-wolf). In order to be able to say that the prime had an effect on the response to the target, shorter response times (RT) should be found for congruent pair trials as compared to incongruent pair trials. This type of outcome is known as priming congruence effect (Ortells et al., 2016). If the prime stimulus is not consciously perceived, it could be hypothesized that the influence it had on behavior is due to non-conscious processing. As a result, we refer to the priming effect as "subliminal" (Figure 1).

In order to inquire about non-conscious information processing, the masked prime must generate a non-conscious processing of the prime stimulus. Therefore, all the methodological characteristics necessary for the priming effect to occur must be plainly clarified (i.e., the exact time of stimuli presentation, size, shape, type and duration of masks, etc.). Unfortunately, all the variables that could influence subliminal visual masking are not well known yet (Bachmann & Francis, 2013) and several researchers do not agree on how to test prime stimulus visualization. As a result, undergoing this paradigm turns into a time demanding trial and error attempts in the search for the optimal outcomes.

Therefore, since the study of conscious and non-conscious processes constitutes a genuine challenge to neuroscientists, a better understanding of the most used experimental approach seems fundamental to achieve that goal. The present paper aims to discuss the scientific findings related to the methodological characteristics of the masked priming paradigm applied to the different studies of conscious or non-conscious processes like semantic, emotional and attentional processes. On the other hand, we will address some of the most common problems associated with the methodology used in those studies like the format of the stimuli, the masks to be used, visibility measures and the selection of the Stimulus Onset Asynchrony (SOA). This article intends to enable and ease the work of researchers who investigate the phenomenon of consciousness through the use of the masked priming paradigm.

2. Cognitive processes studied using masked priming.

2.1 Semantic processing

One of the questions that have been addressed through the masked priming paradigm is: To what extent a given stimulus can be analyzed through a non-conscious process? For example, if a subliminal priming effect is based on relatedness of meaning between the prime target stimuli (i.e., skate-dance vs. talk-dance), it could be said that there is a non-conscious semantic level of processing for that pair of stimuli (Collins & Loftus, 1975). Several theories attempted to explain the semantic process of the priming stimulus through a masked priming paradigm (McNamara, 2005). Whether non-conscious processing could reach semantic levels was long debated (Shelton & Martin, 1992). That is, a word not consciously perceived is, in any case, processed semantically (Kouider & Dehaene, 2007). In 1998, Dehaene et al. designed a task in which the participants had to categorize certain numbers (1, 4, 6, 9) as greater or less than 5. This classification is semantic in nature since it appeals to semantic knowledge associated with numbers. They found a congruency effect when the prime stimuli were reported as not consciously perceived. Therefore, they inferred that the masked prime is subject to nonconscious semantic processing. This statement had great theoretical implications, since traditionally, automatic processing has been considered as not allowing a high level processing as is the case of semantic processing (Pohl et al., 2010). In other words, this type of processing might happen in an automatic manner, without getting involved in highly complex functions, as opposed to conscious processing, which is capable of performing complex cognitive tasks, such as the semantic categorization of stimuli (for example deciding whether a number is greater or less than 5). Nonetheless, some alternative interpretations of the results found by Dehaene et al.

(1998) have been proposed. A first alternative explanation was that of Damian (2001), who stated that, because the target stimuli used by Dehaene et al. (1998) were the same as the prime stimuli, thus, all stimuli were consciously perceived and the participants in the experiment could have established stimulus-response associations when responding to a target stimulus (i.e., the perception of the number 9 is strongly associated with pressing a button with the right hand), and then activated that same response in a non-conscious automatic way when this stimulus appeared as prime (ie, number 9 = right hand). In this way, semantic processing could be ignored for the explanation of the results obtained by Dehaene et al. (1998). In order to overcome this non semantic explanation, the stimuli that are presented as targets should not be also presented as prime stimuli, thus, avoiding stimulus-response associations with the prime (Damian, 2001). The second alternative explanation was made by Kunde et al., (2003), who indicated that all possible stimuli to be used as a target (those less than 5, that is, 1, 2, 3, 4 and those greater than 5, these are 6, 7, 8, 9) could have been inferred by the participants from the slogan and the practice tests. Therefore, participants could have prepared responses to answer each stimulus when presented as a target or masked prime.

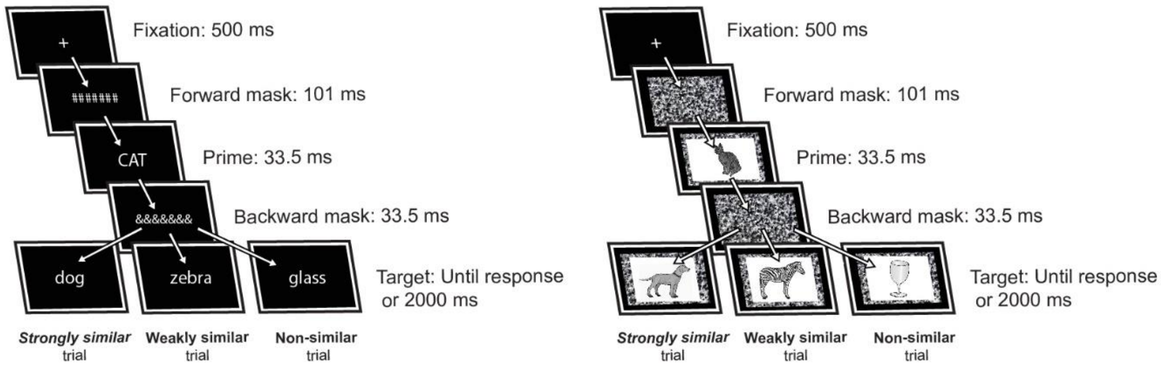

Figure1. Typical example of masked prime trials with verbal stimuli (left) and pictorial stimuli (right). Subjects must decide if the target stimulus is an animal or an object. Prime stimulus (cat) is strongly, weakly or not related to the target (taken from Bruno et al., 2020 with permission).

That is, in addition to having inferred the possible target stimuli that were going to be presented to them, which they were going to have to categorize, the participant could have prepared responses to give (ie 1, 2, 3, 4 = left hand; 6, 7, 8, 9 = right hand), and therefore, when those stimuli were presented in a masked manner, they would be pre-activating previously prepared motor response, without the need for semantic processing. It also implied being able to ignore the semantic processing of the prime as an explanation for the results obtained by Dehaene et al. (1998). To avoid this alternative explanation, broad categories such as animals or objects should be used instead of small ones such as numbers from 1 to 10. This way, as the list of possible stimuli could not be easily inferred, the anticipated prepared responses for those stimuli could not be made or at least they should be of little help at the time of processing the prime stimuli (Kunde et al., 2003). Currently, the idea that non-conscious processing reaches semantic levels has considerable evidence for it (Bruno et al., 2020; Ortells et al., 2013, 2016; Pohl et al., 2010; Van Den Bussche et al., 2012). There is even evidence that a semantic integration of more than one word can occur without awareness (Nakamura et al., 2018; van Gaal et al., 2014). Furthermore, some authors have even considered studying its scope (Nakamura et al., 2018; Van Den Bussche et al., 2012; van Gaal et al., 2014). For example, Van Den Bussche et al. (2012) found that congruent pairs do not always elicit a non-conscious semantic congruence priming effect. Apparently, it was necessary that these concepts were strongly similar, that is, that they share more than one semantic characteristic in common, as in the case of dog-cat (animals and domestic) and not as in the case of dog-bull (only animals; McRae & Boisvert, 1998; Ortells et al., 2016). In the results of their study, Van Den Bussche et al. (2012) found that congruent pairs that were weakly similar, such as dog-bull, did not produce a priming effect of congruence under masking conditions. In two other recent studies, (Ortells et al., 2013, 2016) found these same results, although strongly similar pairs were also strongly associated, understanding the latter as those concepts that typically appear together or with a high probability that a concept brings to mind another concept even though they do not share common characteristics, such as pieta-michaelangelo (McRae & Boisvert, 1998). These studies suggest that the congruence between the prime and the target (that is, that both are of the same category and therefore correspond to the same answer button), is not enough to observe a priming effect of semantic congruence at non-conscious levels. Rather, to observe this effect, it would be necessary for the prime and target stimuli to be strongly semantically related, that is, to have a high similarity and a strong semantic association (Ortells et al., 2016). However, a recent study seems to cast doubt on the latter. In 2020, Bruno et al. observed that weakly similar pairs produced an effect analogous to strongly similar pairs, both for stimuli of a verbal and pictorial nature (Bruno et al., 2020). This last study, allows us to infer that the results of (Ortells et al., 2016) could be due more to semantic association than to semantic similarity. Nevertheless, this question requires further investigation to be resolved.

2.2 Emotional processing

Affective masked priming techniques evaluate the influence the emotional content of a subliminal stimulus exerts on the evaluation of the target stimulus (Lohse & Overgaard, 2019). That is, instead of the prime stimulus facilitating the semantic processing of the target stimulus, in this case it is expected that the prime modulates the emotional processing towards the target stimulus. Just as the effects of the semantic congruence priming are generally obtained in semantic classification tasks, the affective congruence priming effects are usually obtained in evaluative classification tasks (Lohse & Overgaard, 2019). In these tasks participants are presented with a series of stimuli and are instructed to categorize them. For example, participants are presented with a series of words and are asked to categorize them as being either emotionally positive or negative (Ferré & Sánchez-Casas, 2014). Affective priming arises from the affective primacy theory first proposed by Kunst-Wilson & Zajonc (1980), according to which participants could develop affective preferences towards a stimulus without its conscious recognition The experiment was divided into an exposure phase and a recognition phase. During the exposure phase, participants were subliminally exposed through a series of flashes to a block made up of ten octagons, and then followed by a recognition phase. In the recognition phase the participants were presented with five pairs of octagons. An octagon of the block to which the participants had been previously exposed, and another novel octagon. The participants were asked their affective preference between both geometric figures, indicating which of the figures they liked the most and which of the figures they thought had been previously presented. Most of the participants expressed having preference towards figures of the block to which they had been previously exposed to, thus developing preferences towards the octagons by means of repeated exposures. These results provide evidence that affective discrimination can be carried out without explicit conscious recognition. In addition, Kunst-Wilson & Zajonc (1980) argue that affective states can be modulated non-consciously. In the same line of research, Murphy & Zajonc (1993) tested the hypothesis of affective primacy through an affective masked priming paradigm. They used targets composed of chinese ideograms, without a clear affective connotation for western participants, while they used primes of facial expressions that represented emotions. In one of the experiments, the participants were instructed to give their evaluation of the targets on a scale that ranged from 1 ("I don't like it at all") to 5 ("I like it a lot"). In the subliminal condition, the participants gave the target a "negative" value when they were preceded by negative facial expressions, compared to when they were presented with positive facial expressions. These results provided validity to the affective primacy hypothesis insofar as they allowed us to infer that it is possible to modulate the affective state in a non-conscious way through a masked priming task. Since then, masked affective priming techniques have been used in various experimental contexts, such as the study of subjective evaluations of participants. For example, affective masking priming techniques have been used in order to modulate the aesthetic evaluations of people (Era et al., 2015), product evaluations (Winkielman et al., 2005), moral judgments (Ong et al., 2014), and racial prejudice (Degner et al., 2007). At the same time, affective priming tasks have faced some methodological and theoretical criticisms, with some authors proposing that the affective priming effect is simply a variant of a typical semantic priming effect. As a result, emotional relatedness may just be another form of semantic relatedness (Kemp-wheeler & Hill, 1992). However, posterior studies (Matthews et al., 1995; Rossell et al., 2000) point to the importance of the affective valence of prime and target pairs in order to produce robust priming effects. However, the level of semantic relatedness between primes and targets in masked affective priming paradigms is an ongoing topic of debate.

2.3 Attentional processing

The masked priming paradigm has also been used to study attentional processing (Dehaene et al., 2006; Kouider & Dehaene, 2007). The hypothesis behind these studies is that attention could modulate non-conscious processes (Naccache et al., 2002; Xiao & Yamauchi, 2017). For example, Naccache et al. (2002) used the masked priming paradigm to observe if a prime stimulus was processed when it appeared in a moment that was not predictable by the participant (and therefore outside the attentional window). With this objective, a similar task to that of Dehaene et al. (1998) was carried out, where the participants had to choose whether a target digit was less than or greater than 5, preceded by a masked prime digit, sometimes congruent and other incongruent with the target. The novelty of this study is that it directly manipulated the attentional temporal window of prime processing using two conditions. In one of them, a green square was presented before the presentation of the prime and the target in a way that the participant knew the target was about to appear (attended condition). Participants did not know of the existence of the prime, however, given that the green square was presented before the prime, it could take advantage of the attention resources destined to the target. In the other condition, the green square was not present (and given that the time before the prime varied in both conditions), it was impossible to predict exactly when the target stimulus would appear (unattended condition). The authors observed an non-conscious congruence effect only for the attended condition. The results were interpreted by the authors as evidence that the prime stimulus must enter into the attentional time window for non-conscious congruence effect to be observed. Subsequently, Xiao & Yamauchi (2017) used a similar procedure to Dehaene et al. (1998), although modifying the duration of the second mask of the prime stimulus. In this way, they obtained different temporal distances between the presentation of the prime and the presentation of the target (SOA). Their design considered 4 times of SOA and two attentional conditions, attended and not attended, (see Naccache et al., 2002). These authors observed a non-conscious congruence effect for the first three times of SOA (50ms, 200ms and 500ms) in the attended condition, and only for the second time of SOA (200ms) in the unattended condition. Furthermore, in this study it was found that the time course of masked semantic priming was modified by attention. To observe this, the congruence effect was calculated for each SOA time and according to whether it belonged to the attended condition or not. The time course found for the attended condition was a quadratic trend, while in the unattended condition the trend was linear. From these results, it could be inferred that attention, like many other cognitive processes, can be modulated non-consciously and that the SOA must be taken into account as an important factor modulating priming effects under a masked priming study (Dehaene et al., 2017). Another study that dissociated conscious and non-conscious processing targeting attention was Kiefer & Martens (2010). These authors used the masked priming paradigm with certain modifications to analyze whether attention could be sensitized to process the masked prime in a perceptual or semantic way. With this in mind, a two-part task was designed. The first part was called the induction task, it was developed to induce either perceptual or semantic processing. The second part consisted of a lexical decision task, where the masked priming paradigm was used. In the perceptual induction task, participants had to decide whether a word had a first or last letter with a closed form (i.e., "d" in "doctor") or whether the first and last letters had an open form (ie "r" in "run "). In the semantic induction task, participants had to decide whether or not a word represented a living being. On the other hand, in the lexical decision task, participants had to decide whether a target stimulus was a word or a pseudoword. Before the target presentation, a masked prime stimulus was shown, sometimes congruent and at other times incongruent to the target. Participants performed an induction task and, afterwards, a lexical decision task in each trial. The induction task was perceptual or semantic in nature. The idea of this design was to sensitize attention through the induction task and observe possible effects on the semantic processing of the prime. The results revealed that the congruence priming effect in the lexical decision task increased when the induction was semantic in nature and the effect was attenuated when the induction was perceptual in nature.

Based on these results, the authors concluded that the induction task could modify the way in which the prime stimulus was processed non-consciously, by sensitizing attention. This would imply that the automatic and non-conscious processing of the prime may be due to attentional mechanisms (Kiefer et al., 2019; Kiefer & Martens, 2010). In addition, it has been suggested that, in order to observe non-conscious attentional processing of the masked stimulus, it is a necessary condition to consciously instruct participants in a top-down manner (that is, with an allocation of conscious attention by the participant) on a task that predisposes them to be subliminally influenced by the prime stimulus (Ansorge et al., 2014). Since non-conscious processing is rapid and involuntary, tasks in semantic and attentional priming indicate the importance of instructions when specifying the task that the participant must perform, especially in cases in which the relationship between the prime and the target are ambiguous (Ansorge et al., 2014) because it has implications on how participants process a stimulus. However, there are certain stimuli such as those with emotional characteristics (like facial expressions) that, due to their emotional salience, could generate a priming effect on their own, without a instruction in between (Ansorge et al., 2014), summoning attentional resources from the participants, even outside an explicit top-down attention allocation.

3. Methodological considerations in the masked priming paradigm.

The stimulus format, the characteristics of the mask, the measures of prime visibility and the SOA are some of the crucial variables present in all the aforementioned studies. Even a little modification in any of those variables could completely alter the results and thus, it could change data interpretation. Therefore, presenting and discussing each of those variables could be of great help in the search of conscious processes through a masked priming paradigm.

3.1 Stimulus format

Different formats of prime and target stimuli have been used in semantic priming studies, such as numerical (i.e., Dehaene et al., 1998; Naccache et al., 2002; Xiao & Yamauchi, 2017), 2) verbal (i.e., Bruno et al., 2020; Ortells et al., 2013, 2016), or 3) pictorial (Bruno et al., 2020; Pohl et al., 2010). Some studies even use more than one format at a time (i.e., Bruno et al., 2020; Dell'Acqua & Grainger, 1999; Van Den Bussche et al., 2012). One of the main findings of those studies was that the format in which the prime and the target stimuli are presented can modulate priming effect results (Van den Bussche et al., 2009). For example, some studies have concluded that pictorial stimulus seemed to be categorized more quickly than words in a semantic categorization task (Bruno et al., 2020; Kiefer et al., 2015; Smith & Magee, 1980). A possible explanation for this effect is that pictures would have privileged access to semantic content in the brain (Glaser, 1992), while words would access phonemic information faster (Andreau & Torres Batán, 2019; Durso & Johnson, 1979). In a meta-analysis paper, Van den Bussche et al., (2009) highlighted the fact that the stimulus format is irrelevant regarding priming effect. However, it is important to mention that they analyzed words and symbols (digits, letters, pictures or chinese symbols) as different stimulus formats and did not include pictorial stimuli which have shown a very strong priming effect (Ortells et al., 2013, 2016). Therefore, it remains unclear for example whether pictures would elicit a stronger nonconscious priming effect than words. In 2020 Bruno et al. compared the priming congruence effect with pictorial and verbal stimuli under a semantic categorization task using the masked priming paradigm. Although they replicated the well-known result that, in semantic tasks, images are categorized more quickly than words, they did not find a difference in the priming congruence effect depending on the stimulus format. Taking these results into account, the authors concluded that although the stimulus format has differential processing levels in semantic categorization tasks, this difference does not affect the priming congruence effect. Nevertheless, more research is needed to clarify this point.

3.2 Masking the prime stimulus

A mask is understood as the stimulus used to hinder a conscious perception of the prime stimulus. The choice of the mask is crucial since the type of mask will affect the processing of the prime (Bachmann & Francis, 2013). In their work, Van Opstal et al., (2005) explained: "[...] even an apparent detail such as the composition of the mask, can lead to different results and should be taken into consideration in priming studies." Just as the prime stimulus can be of different formats, the masks can belong to the most varied designs, ranging from light, visual noise, patterns, objects or metacontrast masks (Bachmann & Francis, 2013). In this way, a mask composed of letters in a task where the prime stimulus is also composed of letters, would result in a greater priming effect compared to a mask that is composed of other symbols such as hashtags. On the other hand, some authors argue that the priming effect would not be greatly modulated by the type of mask used. In a meta-analysis on masked priming (Van den Bussche et al., 2009) observed that the type of masking did not modulate the congruence effect (Although this work did not consider another key variable for the evaluation of the mask, which is "how many" times the mask is presented). In view of these contradictory conclusions, it is necessary to clarify every aspect of the mask stimulus. This means not only its format but also when this mask is presented in the task. For example, if it only appears before the prime, it is called "forward" masking. If it only appears after the prime it would be "backward" masking (Bachmann & Francis, 2013). It can also happen that the prime stimulus is masked by a stimulus that appears before its presentation, and after its presentation, in this way, the prime stimulus is masked by means of a "simultaneous masking" (Figure 2) or also called sandwich masking (Holender & Duscherer, 2004). Regarding the metacontrast masking, unlike other types of masks, it consists of a variety of backward masking where the mask does not overlap with the time window occupied by the prime, but temporarily appears very close to it (Bachmann & Francis, 2013). This procedure can be performed by forward masking, in this case being called paracontrast masking (Bachmann & Francis, 2013). There is plenty of literature that describes how the type of mask influences the visibility and processing of the prime, however, this discussion is beyond the purposes of this work (For a review on visual masking see Bachmann & Francis, 2013). It is important to mention that finding the ideal mask that makes it difficult to perceive the prime stimulus (without preventing it from being processed) is a difficult and complex task. For this reason, it is essential to carry out pilot studies prior to the experimental task. The usual methodologies to verify the effectiveness of the mask in the perception of the prime stimulus are detailed below.

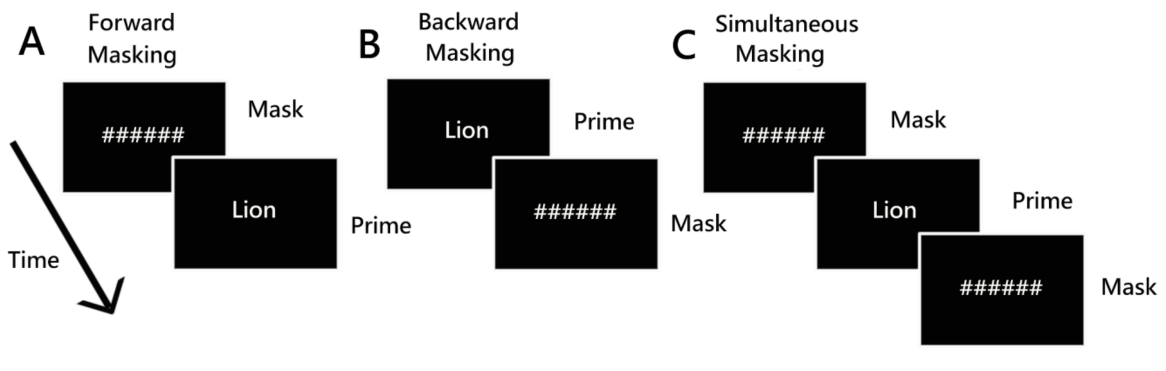

Figure 2. Examples of the different time presentations for the mask. For this example, we used words as stimuli and hashtags as masks. A. Forward masking, B. Backward masking and C. Simultaneous masking (a.k.a. sandwich masking).

3.3 Prime visibility measurements

In order to confirm if a stimulus was processed in a non-conscious way, we must demonstrate at least two principal aspects: a) that the prime stimulus was processed by the participants and influenced their behavior and b) that the prime stimulus was not consciously perceived. In most studies, correct responses are used as dependent variables to measure if a certain stimulus was processed non-consciously (Seth et al., 2005). For example, it can be stated that a person is aware of a red light because she/he said the light was red. In this way, to prove that a stimulus is non-consciously processed, the participant should get the wrong answer when asked about the subliminal stimulus (i.e., say it was red when in fact it was green). Therefore, it is important to define a way to measure this prime visibility. Again, based on the methodology used, we can get different results.

There are several ways to measure prime visibility (Seth et al., 2008). Although there is no consensus on a single best approach to analyze prime visibility, there are subjective and objective approaches to do this (Boly et al., 2013). The subjective approach consists in asking the participant, after finishing the experimental task, if she/he saw the prime stimulus. It does not necessarily have to be a "yes" or "no" answer. It can also consist of a scale that ranges from "totally seen" to "not seen". The objective approach requires the experimenter to repeat the same structure of the task but using different instructions, so that the new task asks participants to categorize the prime stimulus and not the target stimulus (i.e., Damian, 2001; Kunde et al., 2003; Pohl et al., 2010; Van Den Bussche et al., 2012). The main idea behind this measure is to compare the outcomes obtained with what would be expected to result by chance. Using the signal detection theory (Macmillan & Creelman, 2004) it is possible to quantify the participant's ability to detect whether a stimulus is a "signal" (the stimulus to be detected) or "noise" (the stimulus other than the signal). When masked priming paradigm is applied to semantic categorization tasks (i.e., Animals vs Objects), a whole category could be used as a signal (i.e., Animals) and the other category could be used as noise (i.e., Objects). In this way, during the categorization of the prime stimulus, participants can correctly detect the signal stimulus (i.e., saying that the prime stimulus was an animal when it was indeed an animal; Hit), or incorrectly detected a noise stimulus as a signal stimulus (i.e., saying that the prime stimulus was an animal when it was actually an object; False Alarm). Once these measures are obtained, the number of Hits is divided by the total number of stimuli that were considered as signal, obtaining the "hit rate" (h), and the number of False Alarms is then divided by the total number of stimuli that were considered as noise, obtaining the "false alarm rate" (fa). Then the value of d ', which is the sensitivity measure, is calculated from the following formula:

$(\Phi\text{-}1)$:
$d' = \Phi\text{-}1(h) - \Phi\text{-}1(fa)$
Being Φ-1 the inverse of the normal

Once the d' has been calculated for each participant, the average is contrasted against 0. If d' is not significantly different from 0, it indicates that the hit rate and the false alarm rate are similar, implying an inability to discriminate the signal stimuli of those that were noise. On the other hand, if d' is significantly different from 0, it could be said that participants did not respond by chance.

Although some studies only measure visibility subjectively (i.e., Brocher & Koenig, 2016) and others only objectively (i.e., Damian, 2001; Kunde et al., 2003; Pohl et al., 2010; Van Den Bussche et al., 2012), several studies use both measures (i.e., Bruno et al., 2020; Del Cul et al., 2007; Kiefer et al., 2015, 2017; Ortells et al., 2013, 2016). Although a small difference can be found, both measures usually correlate well (Del Cul et al., 2007). Nonetheless, it is important to mention that it has been observed that both measures are not equivalent (Del Cul et al., 2009). For example, participants could perform above what would be expected by chance during objective measure while subjectively denying seeing the stimulus (Dehaene, 2011). Moreover, many subtle variations in the task at hand could affect the prime visibility (i.e., target stimulus format and SOA; [Vermeiren & Cleeremans, 2012], the task difficulty [Pratte & Rouder, 2009], the nature of the prime-target relation [Bernstein et al.,1989; Dark, 1988; Dark & Benson, 1991; Kouider & Dehaene, 2007; McNamara, 2005], and the type of masking used [see Bachmann & Francis, 2013]). Finally, there is another measure of visibility for those studies in which the objective measure based on the signal detection indicates that the prime has responded above chance. It consists in the performance of a linear regression analysis on the d′ values. The intercept of the regression line with the y-axis should be significant when there are priming effects in spite of the absence of prime visibility (Greenwald et al., 1996, Bruno et al., 2020; Naccache & Dehaene, 2001; Ortells et al., 2013, 2016; Pohl et al., 2010).

3.4 The SOA

The SOA, as described above, is the acronym for stimulus onset asynchrony, which generally refers to the time ranging from the first appearance of the prime to the first appearance of the target (i.e., Bruno et al., 2020). However, it has also been used to refer to the time that separates the target stimulus from the mask (i.e., Del Cul et al., 2007). There is evidence suggesting that the SOA is an important modulator of the priming congruence effect (Van den Bussche et al., 2009), as well as of the visibility of the prime stimulus (Bachmann & Francis, 2013). Greenwald et al., (1996) observed that the masked semantic priming effect tends to be of very short duration as compared to when the prime is visible. These authors stated that, in order to observe a subliminal priming congruence effect, a SOA of less than 100ms is necessary since this effect decreases as the SOA time increases. The opposite has been observed in those studies that use a stimulus-response masked priming paradigm (where the prime is processed at the perceptual level). These studies found that the priming congruence effect increases as the SOA increases (Van den Bussche et al., 2009). Regarding affective priming, the reviewed literature seems to agree with the fact that there are greater effects of affective priming in subliminal conditions with short SOAs over supraliminal conditions with longer SOAs (Fazio, 2001; Fazio et al., 1986; Hermans et al., 2001, 2003; Jiang et al., 2016). One possible hypothesis for this speed is due to the role that emotions have in survival. They would be detected quickly when the SOA is short, while when the SOA is long, it could result in an "attenuation" of the affective information of the prime (Fazio, 2001; Jiang et al., 2016). According to Hermans et al. (2001), affective priming appears to be a rapid activation process that has a maximum activation peak at a SOA of 150ms that begins to fade after an SOA of 300ms.

4. Conclusion

The scientific study of consciousness is one of the greatest challenges of our times. Many new studies have revealed very interesting data regarding conscious as well as non conscious processes. There are many paradigms currently used to achieve this goal. The masked priming paradigm has been proved to be one of the best approaches to study the characteristics as well as the extent of non conscious processes. It has been applied to a great variety of fields like semantic, attention and emotional processes. Nevertheless, it is of paramount importance to understand that when studying something as delicate as non conscious processes, attention should be paid to every little aspect. In this article, we mention and discuss many of those aspects. For example the stimulus format could affect the level of processing, the masks can hindered perception, visibility measures can modify the concept of subliminal and the SOA can weaken the masked priming effect. Also the instructions given to the participants (i.e., when given in a top down manner) could influence their performance. Therefore, each one of these variables, as well as the interaction between them, could affect the results and therefore lead to misinterpretation of the data. Masked priming is a legitimate procedure for the study of non-conscious processes both at the level of semantic and emotional processing. However, the methodology to be followed for its application must be considered in detail and exhaustively. Throughout this work, current literature has been reviewed and discussed to advance on questions within the study of semantics, emotion and attention, and some methodological considerations that could be relevant to those researchers who are going to use this paradigm. Finally, while this paradigm has proven to be a powerful tool for investigating some questions, there is still much to investigate in the field of visual masking, so many factors influencing the results are waiting to be discovered (Bachmann & Francis, 2013). Although this is a call to those researchers who are interested in studying this paradigm, it also highlights a detail that is extremely important, be cautious with the data interpretation.

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