Automaticity: Componential, Causal, and Mechanistic Explanations

Agnes Moors[1,2]

[1]Research Group of Quantitative Psychology and Individual Differences; Centre for Social and Cultural Psychology, University of Leuven, 3000 Leuven, Belgium;
email: Agnes.Moors@ppw.kuleuven.be

[2]Department of Experimental Clinical and Health Psychology, Ghent University, 9000 Ghent, Belgium

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Abstract

The review first discusses componential explanations of automaticity, which specify non/automaticity features (e.g., un/controlled, un/conscious, non/efficient, fast/slow) and their interrelations. Reframing these features as factors that influence processes (e.g., goals, attention, and time) broadens the range of factors that can be considered (e.g., adding stimulus intensity and representational quality). The evidence reviewed challenges the view of a perfect coherence among goals, attention, and consciousness, and supports the alternative view that (*a*) these and other factors influence the quality of representations in an additive way (e.g., little time can be compensated by extra attention or extra stimulus intensity) and that (*b*) a first threshold of this quality is required for unconscious processing and a second threshold for conscious processing. The review closes with a discussion of causal explanations of automaticity, which specify factors involved in automatization such as repetition and complexity, and a discussion of mechanistic explanations, which specify the low-level processes underlying automatization.

Contents

INTRODUCTION

Automaticity is a central phenomenon in psychology. The scientific explanation of a phenomenon typically spans the following stages: (*a*) the choice of a provisional demarcation or working definition of the phenomenon; (*b*) development of an explanation, which links the to-be-explained phenomenon (explanandum) to an explaining fact (explanans); (*c*) testing of the explanation in empirical research; and (*d*) if the explanation is sufficiently supported, entering of the explanans in the definition of the phenomenon, which is now a scientific definition (Bechtel 2008).[1] This logic can be applied to automaticity as well. Starting point are descriptions of the phenomena of automaticity as they are experienced by laypeople in daily life, either in the form of a list of features or a list of prototypical exemplars. As an illustration of features, people tend to call a process or behavior automatic when it seems to run by itself, while their mind is elsewhere, when they are unable to prevent or stop it, and/or when it happens fast. Examples of prototypical automatic processes include reflexes or emergency reactions (e.g., eye blinking, retracting one's hand from a hot stove, and vigilant attention shifts), skilled processes (e.g., riding a bike, typing, and playing the piano), and impulsive processes (e.g., lashing out in anger, eating the bowl of nuts in front of you, and compulsive thoughts).

Starting from this provisional demarcation, theorists have proposed componential, causal, and mechanistic explanations for automaticity. A componential explanation unpacks the components of automaticity and specifies the relations among them. A causal explanation of the automaticity of a process specifies the factors involved in the transition of a process from nonautomatic to automatic, also called automatization. A mechanistic explanation of the automaticity of a process specifies the low-level processes underlying automatization. Both componential and mechanistic explanations span different levels of analysis (Bechtel 2008, Marr 1982). It is useful to distinguish between

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[1] For an example from chemistry, water (explanandum), provisionally demarcated with superficial features (e.g., clear, odorless fluid, falling out of the sky) has been explained by linking it to H_2O (explanans). Abundant empirical confirmation of this explanation has eventually led to a redefinition of water as H_2O.

an observable level, a set of hidden levels, and a brain level: On the observable level, a process is described as the transition from an observable input to an observable output. On the hidden levels, the process is decomposed into subprocesses, which can themselves be described in terms of their inputs and outputs. Intermediate, hidden inputs and outputs are called representations. Each of the subprocesses can be decomposed in even finer-grained subprocesses, until, at the ultimate stages of decomposition, they correspond to brain processes. This article discusses existing proposals for componential, causal, and mechanistic explanations of automaticity and reviews the empirical evidence in their favor or against them.

Control: *A* has control over *X* when *A* has a goal about *X* and the goal causes fulfillment of the goal

COMPONENTIAL EXPLANATIONS

Automaticity has been decomposed into a number of components, called automaticity features. Examples are: uncontrolled in the promoting and counteracting sense, unconscious, efficient, and fast. Authors vary with regard to the features they put forward and the relations they assume among them. Some theorists focus on efficiency (Shiffrin 1988), others emphasize lack of control (Posner & Snyder 1975), and still others include the entire list (Bargh 1994). Given the divergence among authors, it is best to always specify the features one has in mind when calling a process automatic.

This section starts with a brief demarcation of the listed features (i.e., components) and a specification of their ingredients (i.e., subcomponents; for an in-depth analysis and a more extensive list of features, see Moors & De Houwer 2006a). It goes on to argue that features are not intrinsic to processes but point at conditions under which processes can occur (Bargh 1992), or more generally, factors that can influence processes. This opens the door for considering the role of factors that do not traditionally belong to the automaticity concept. After describing these factors, the section discusses possible relations among them and reviews the empirical evidence in favor of or against these relations.

Features

Un/controlled. A process is controlled by a person when three ingredients are in place: (*a*) The person has a goal about the process, that is, a representation of a desired state; (*b*) the desired state occurs; and (*c*) there is a causal relation between the goal and the occurrence of the desired state. Goals can be of the promoting kind (i.e., the goal to engage in a process) or of the counteracting kind (e.g., to prevent, change, or interrupt the process). Accordingly, a process can be controlled in the promoting sense (i.e., caused by the goal to engage in it) or in the counteracting sense (i.e., counteracted by the goal to counteract it). Another word for controlled in the promoting sense is intentional. A process is uncontrolled if one (or more) of the three ingredients is lacking: The goal is absent, the desired state does not occur, or the causal relation is absent.

Un/conscious. Philosophers traditionally distinguish two ingredients of consciousness: (*a*) an aboutness aspect, denoting the content of consciousness (e.g., the apple in front of me, a prejudice toward someone), and (*b*) a phenomenal aspect, denoting the subjective quality or "what it is like" to be conscious of something (e.g., what it is like to see the redness of the apple or to entertain the prejudice; Block 1995). If a process is conceptualized as the transition between an input and an output, being conscious of a process boils down to being conscious of the input, the output, and the transition from one to the other. A process is unconscious when one or more of these three elements is missing.

Non/efficient. A process is called efficient versus nonefficient if it requires little (or no) versus a substantial amount of attentional capacity (Shiffrin 1988). The ingredient at stake is attentional capacity or the amount of attention. In addition to quantity, attention also has a quality or direction, which is partly independent from quantity: Directing and allocating attention requires some amount of attention (Konstantinou & Lavie 2013), but it may not require a lot.

Fast/slow. A process is fast versus slow when it requires little versus much time or when it has a short versus long duration. The ingredient at stake here is time or duration. The duration of a process should not be conflated with the duration of its input. A fleeting stimulus may trigger a slow process, and an enduring stimulus may trigger a fast process.

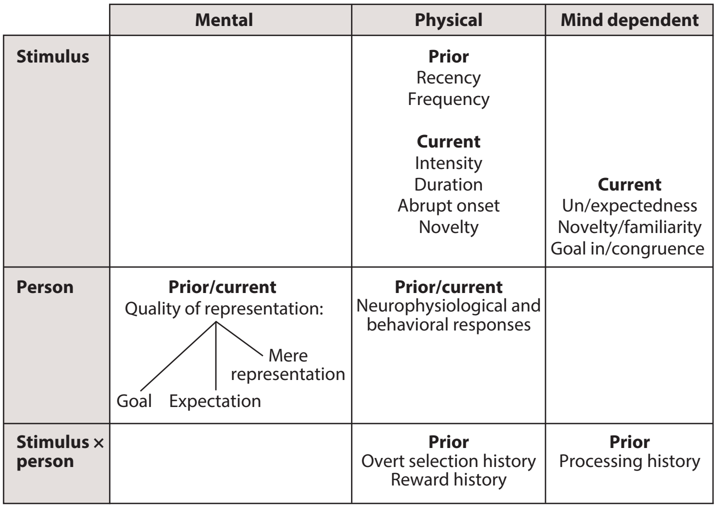
Like efficiency, speed is most naturally considered as a gradual feature. The feature controlled can be considered to be a gradual feature as well: A goal can be partially or entirely reached. The gradual nature of consciousness is debated: Some findings favor a continuous transition from unconscious to conscious processing (Moutoussis & Zeki 2002, Nieuwenhuis & De Kleijn 2011), whereas others favor a discontinuous one (Sergent & Dehaene 2004).

Extending the Range of Factors

The view defended here is that non/automaticity features are not intrinsic to processes, but point at conditions under which processes occur or at factors that influence their occurrence (Bargh 1992). Thus, a process is uncontrolled in the promoting sense if it is not caused by the goal to engage in the process, uncontrolled in the counteracting sense if it is not counteracted by the goal to do so, unconscious if it occurs in the absence of consciousness (of the input, the output, and/or the transition from input to output), efficient if it occurs when attentional capacity is scarce, and fast if it occurs in a short time interval.

One could argue that the range of factors that can influence the occurrence of processes goes beyond those that are traditionally covered by the automaticity concept. In principle, any aspect of the experimental procedure (and beyond) can influence processing, but researchers tend to focus on those factors that generalize across experiments and from which they expect a high explanatory power. Factors can be organized in a taxonomy according to at least six combinable axes (see **Figure 1**): (*a*) procedural versus nonprocedural, (*b*) current versus prior, (*c*) person versus stimulus (and person × stimulus), (*d*) physical versus mental (and mind dependent), (*e*) absolute versus relative, and (*f*) occurrent versus dispositional. A brief clarification of these notions now follows.

(*a*) Procedural factors are induced by the procedure of an experiment (e.g., the stimulus set); nonprocedural factors are not (e.g., a participant's personality). (*b*) Current factors are present here and now; prior factors were present in a prior part of the procedure or at a time before that (e.g., learning history). (*c*, *d*) Next are person and stimulus factors. Person factors can be physical (e.g., fatigue, genetic makeup) or mental. Examples of mental person factors are the presence and availability of a stimulus representation (in long-term memory) and the level and duration of its activation (in working memory). It is useful to distinguish at least three types of representations: goals (i.e., representations of desired stimuli), expectations (i.e., representations of expected stimuli), and mere stimulus representations (i.e., representations of stimuli that are neither desired nor expected). Other mental person factors are the amount and direction of attention. Attention can be directed to a spatial location, a time window, the input of a process (an external stimulus or feature, or an internal representation), the output of a process (an internal representation or an external response), or the process itself (i.e., the transition from input to output). Stimulus factors can be physical or mind dependent. Physical stimulus factors comprise current factors such as duration and intensity (subsuming factors such as contrast, luminance, size, and movement), or



	Mental	Physical	Mind dependent
Stimulus		**Prior** Recency Frequency **Current** Intensity Duration Abrupt onset Novelty	**Current** Un/expectedness Novelty/familiarity Goal in/congruence
Person	**Prior/current** Quality of representation: Goal Expectation Mere representation	**Prior/current** Neurophysiological and behavioral responses	
Stimulus × person		**Prior** Overt selection history Reward history	**Prior** Processing history

Figure 1

Examples of procedural factors (cf. *a*) that fit into the intersections of the following axes: stimulus versus person versus stimulus × person (cf. *c*), mental versus physical versus mind dependent (cf. *d*), and current versus prior (cf. *b*).

prior factors, such as frequency or repetition (i.e., the number of times the stimulus was presented before) and recency (i.e., whether the stimulus was presented recently). Mind-dependent stimulus factors are ones that depend in part on the mental state of the participant. Examples are goal in/congruence (i.e., mis/match with a goal, which together form goal relevance or significance; Bernstein & Taylor 1979), un/expectedness (i.e., mis/match with an expectation), and novelty[2]/familiarity (i.e., mis/match with a mere representation; Öhman 1992).[3] Some physical factors refer to the interaction between person and stimuli, such as a person's selection and reward history (Awh et al. 2012). (*e*) All stimulus factors can be absolute or relative. For instance, it makes sense to consider a stimulus' intensity relative to that of other stimuli or to consider a representation's activation level relative to that of other representations. Novelty is often relative to a certain context rather than absolute. (*f*) Finally, most factors are occurrent, referring to actual states (e.g., the activation level of a representation), but some are dispositional, expressing a potential state (e.g., availability and accessibility of a representation).

The proposed taxonomy goes beyond the classical top-down versus bottom-up distinction in several ways. Top-down factors correspond to mental person factors and bottom-up factors to physical stimulus factors. More than a few researchers (e.g., Awh et al. 2012, Theeuwes 2010), however, have extended the category of bottom-up factors with mind-dependent stimulus factors such as unexpectedness and salience (i.e., the capacity of a stimulus to stand out or capture attention; Itti 2007). Yet these factors may be better characterized as referring to the interaction between bottom-up and top-down (Corbetta & Schulman 2002). Moreover, several other factors, such as selection and reward history, fall outside the bottom-up versus top-down divide (Awh et al. 2012). Another problem is the often-made supposition that bottom-up influences are automatic whereas

Goal in/congruence: mis/match of a stimulus with a goal

Un/expectedness mis/match of a stimulus with an expectation

Novelty/familiarity: mis/match of a stimulus with any mere representation (i.e., mind-dependent stimulus factor); "novel" can also mean "never presented" (i.e., physical stimulus factor)

Stimulus intensity: physical stimulus factor subsuming contrast, luminance, size, and movement

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[2] Novelty can also refer to a purely physical stimulus factor, in which case "novel" means "never presented."

[3] Some authors mention the emotional character of stimuli as a factor (Pourtois et al. 2013), but this often can be unpacked as goal relevance, threat value, negativity, valence, or arousal (Sander et al. 2003).

top-down influences are not, although it is rarely specified what is meant by automatic in this context.

A further remark is that mind-dependent stimulus factors have to be manipulated via physical stimulus factors. The latter can be considered as physical counterparts of the former, and the former as mind-dependent counterparts of the latter. For instance, familiarity and accessibility can be considered as mind-dependent counterparts of frequency and recency, respectively. In a similar vein, dispositional factors can be translated in an occurrent counterpart. This is what happens when accessibility is translated in the quality of a representation and when availability of a representation is translated in the existence of a memory trace leading to a representation. The insight that physical and mind-dependent factors can be counterparts of each other helps explain why debates about whether the source of certain effects is physical (e.g., abrupt onset) or mind dependent (e.g., unexpected) are largely pointless. Thus, the multiple-axis taxonomy proposed here not only allows for a larger degree of precision and exhaustivity in the number of factors considered compared to the bottom-up versus top-down dichotomy, but also helps to reveal pseudo discussions.[4]

Relations Among Features/Factors

Now that the features of non/automaticity have been situated within a broader range of factors, the groundwork is laid for examining the relations among these features. At one end of the spectrum is the view that there is perfect coherence among all automaticity features (e.g., uncontrolled, unconscious, efficient, and fast) and among all nonautomaticity features (e.g., controlled, conscious, nonefficient, and slow). This view has various origins. The first origin is ideas of conceptual overlap among features. Examples are the idea that consciousness is an ingredient of "true" control (e.g., Prinz 2004) and that consciousness coincides with attention (e.g., O'Regan & Noë 2001). The second source is ideas about implicational relations (i.e., of necessity and sufficiency) among features or factors. Examples are the ideas that goals are necessary and sufficient for attention (Folk et al. 1992), that attention is necessary and sufficient for consciousness (e.g., De Brigard & Prinz 2010), and that consciousness is necessary for control (e.g., Uleman 1989).

At the other end of the spectrum are proponents of a decompositional view, who argue that the idea of perfect coherence is based on shaky grounds (e.g., Bargh 1992, Moors & De Houwer 2006a, Shiffrin 1988). Each of the sources of the perfect coherence view can be challenged. First, features can be defined in nonoverlapping ways, as is clear from the definitions of control, consciousness, attention, and speed presented in the previous paragraphs. Second, there may be implicational relations among factors (some factors may be necessary *or* sufficient for other factors), but the question is whether these are one-to-one relations (whether one factor is both necessary *and* sufficient for another factor).

To demonstrate that one factor A is necessary for another factor B, one should demonstrate that in all instances in which A is absent, B is absent as well. Because investigating all instances is impossible, researchers often come up with one or more instances in which A and B are both absent, and generalize the conclusions about the necessity of A for B in these instances to all other instances. To demonstrate that A is not necessary for B requires finding only one instance in which A is absent but B is present or one instance in which another condition C is sufficient.

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[4] On a meta-scientific scale, this proposal fits in the general approach to organize any set of phenomena (whether they are factors, processes, or even theories) according to multiple combinable axes instead of into a limited number of categories and to resist accepting untested assumptions of the unity of these categories.

To demonstrate that *A* is sufficient for *B* requires demonstrating that in all instances in which *A* is present, *B* is present as well. Again, because investigating all instances is impossible, researchers collect one or more instances in which both *A* and *B* are present and generalize the conclusions about the sufficiency of *A* for *B* in these instances to all other instances. To demonstrate that *A* is not sufficient for *B* requires finding only one instance in which *A* is present and *B* is absent or one instance in which another condition *C* is necessary. The next sections review the empirical evidence pertaining to the implicational relations among goals, attention, and consciousness (the ingredients of the features un/controlled, non/efficient, and un/conscious). Is it warranted to maintain that (*a*) goals are necessary and sufficient for attention, (*b*) attention is necessary and sufficient for consciousness, and (*c*) consciousness is necessary and sufficient for goals?

From Goals to Attention

This section reviews empirical research pertaining to the influence, necessity, and sufficiency of goals for attention.

Influence of goals on attention. The claim that goals influence attention can be split into the subclaims that (*a*) the content of goals influences the direction of attention and (*b*) the strength of goals influences the amount of attention. Evidence for the first type of influence (content on direction) is abundant (see Awh et al. 2012, Hommel 2010). Spatial cuing studies show that the goal to respond to a target (presence or feature) combined with information about the likely location of the target (provided by a cue that reliably predicts this location) leads to the directing of attention to that location (e.g., Posner 1980). Other studies show that the goal to respond to a target feature (e.g., color) leads to the directing of attention to that feature across space. If the target is defined by a conjunction of features (e.g., color plus location), attention is also directed to nontargets that have feature overlap with the target (e.g., color). This is illustrated by a study of Folk & Remington (1998) in which the task to respond to red targets in one of four boxes increased attention to red (compared to white) dots surrounding the boxes before the targets were presented. In other studies, it is shown that attention is directed to stimuli or features that are relevant not to a current goal but rather to a previous goal or a goal that applies in a different context (e.g., a different type of trials). Vogt et al. (2010) alternated spatial cuing trials with goal trials in which participants had to respond to the words "ship" and "field." They found that attention measured during the spatial cuing trials was directed to the words that were relevant during the goal trials but irrelevant during the spatial cuing trials. Dijksterhuis & Aarts (2010) reviewed studies showing that attention also can be directed by unconscious goals. All of the above-cited studies are concerned with the influence of the goal to respond to a particular stimulus/feature[5] (e.g., red versus green) on the direction of attention. A different line of research is concerned with the influence of the goal to perform a particular action (e.g., grasping versus reaching) on the direction of attention. Müsseler & Hommel (1997) found that the instruction to reach versus grasp an oddball stimulus was facilitated when the oddball was defined in terms of its location (relevant for reaching) versus its size (relevant for grasping).

The second type of influence (strength on amount) is demonstrated in studies in which stronger goals led to stronger attentional bias effects (Engelmann et al. 2009, Libera & Chelazzi 2006). Using a dot-probe task, Mogg et al. (1998) observed that hungry participants attended more to food-related words than neutral words in comparison with nonhungry participants.

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[5] A stimulus can be considered as a collection of features.

Necessity of goals for attention. If instances can be found in which attention is directed by factors other than goals, it can be concluded that goals are not necessary for the directing of attention. Studies using visual search and spatial cuing showed that early attention can be directed by abrupt onsets (Enns et al. 2001, Mulckhuyse & Theeuwes 2010) and by other ways to render stimuli unexpected (Posner et al. 1980). In visual search studies, the observation that the selection of a target defined by color, size, motion, or orientation was not delayed by increasing the number of distractors surrounding it indicates that these features were processed efficiently (i.e., without requiring much attention) and that they guided or directed attention (Wolfe & Horowitz 2004). These and many other studies purport to show that abrupt onsets and other physical stimulus factors are the initial guides of attention and that they are able to override the influence of goals (Belopolsky et al. 2010, Theeuwes 2010). The picture emerging in these studies is that goals can at best adjust the size of the attention window in early stages, but that most of their influence kicks in later (through recurrent feedback processes; Theeuwes 2010). It is further argued that most so-called early influences of goals on attention conceal effects of repetition or selection history (Awh et al. 2012). For instance, the effect found in the study of Folk & Remington (1998) can equally well be explained by repetition priming because the target was kept constant across trials. In stark contrast with this stimulus capture view, proponents of the contingent capture view provide evidence that early effects of abrupt onsets depend in fact on current task goals (e.g., Wu et al. 2014; see also Lamy & Kristjánsson 2013). For instance, in many visual search studies, participants were instructed (and hence presumably had the goal) to search for deviant (or other) stimuli. Thus, it cannot be concluded that the physical features found to guide attention in these studies were sufficient for doing so (Folk et al. 1992). The controversy has led some researchers to adopt a reconciling position, according to which both types of factors contribute to the early directing of attention in an additive way (Kastner & Ungerleider 2000, Pourtois et al. 2013, Wolfe et al. 2003). Lamy & Kristjánsson (2013), for instance, acknowledge the dramatic role of the selection history but still point at studies that provide evidence for the unconfounded influence of goals (e.g., Irons et al. 2012).

In sum, there is debate about whether physical stimulus factors such as abrupt onsets can be sufficient for the directing of attention, but it is clear that selection and reward history independent of current goals can influence attention, which means that at least current goals are not necessary.

Sufficiency of goals for attention. With regard to the sufficiency of goals for attention, it is useful to distinguish between attention search and attention allocation. Attention search can be understood as the directing of attention across the perceptual field while keeping the representation of a stimulus/feature active (Awh et al. 2006). Attention allocation can be understood as the directing of attention to a specific stimulus/feature, a specific location, or a specific time window. Goals may be sufficient for attention search and spatial and temporal attention allocation, but it seems safe to assume that stimulus/feature-based attention allocation also requires the presence of a stimulus with some duration and intensity and with one or more specific features.

In sum, the arguments and empirical evidence reviewed above support the ideas that (*a*) goals do influence attention; (*b*) goals are not necessary for attention, given that other factors seem sufficient in some instances; and (*c*) goals may be sufficient for some forms of attention (attention search and spatial and temporal attention allocation) but not for others (stimulus/feature-based attention allocation).

From Attention to Consciousness

This section reviews empirical research pertaining to the influence, necessity, and sufficiency of attention for conscious processing.

Influence of attention on consciousness. The claim that attention has an influence on consciousness can be split into the subclaims that (*a*) the direction of attention influences the content of consciousness and (*b*) the amount of attention spent on something (stimulus/process) increases the likelihood that it becomes conscious. Evidence for the first type of influence (direction on content) comes from effects known as inattentional blindness (i.e., an unexpected stimulus with a high intensity and long duration fails to reach consciousness when attention is directed to another stimulus; e.g., Mack & Rock 1998) and change blindness (i.e., a change in a visual pattern does not become conscious when attention is not focused on the changing part; e.g., Rensink et al. 1997). Evidence for the second type of influence (quantity on likelihood) comes from effects known as the attentional blink (i.e., a stimulus fails to reach consciousness when attention is consumed by another stimulus that is presented about 200 ms earlier; Raymond et al. 1992) and load-induced blindness (i.e., the threshold for consciousness of a stimulus increases when attentional capacity is consumed by a secondary task; Macdonald & Lavie 2008).

Necessity of attention for consciousness. The idea that attention influences consciousness is uncontroversial, but there is debate about whether it is also necessary for consciousness. A first position is that attention is necessary for all conscious processes, leaning on the metaphor of attention as the spotlight in the theater of consciousness or the gate to a global workspace or working memory in which consciousness is possible (Baars 1988, De Brigard & Prinz 2010, Kouider & Dehaene 2007). A second position is that top-down attention is necessary for some conscious processes or effects (e.g., full reportability, consciousness of unexpected and unfamiliar stimuli; cf. inattentional blindness) but not others (e.g., partial reportability, consciousness of familiar stimuli or the gist of stimuli, pop-out effect in visual search tasks, and iconic memory; Koch & Tsuchiya 2007, van Boxtel et al. 2010). Note that these authors do not exclude the necessity of bottom-up attention for the latter type of conscious effects. A third position is that attention is necessary for one type of consciousness (access consciousness) but not another (phenomenal consciousness; Block 1995, Bronfman et al. 2014).

The empirical effects listed above (inattentional blindness, change blindness, attentional blink, load-induced blindness, and full reportability) all indicate that the absence of attention leads to an absence of consciousness. Critics have argued that the studies merely show an absence of reportability, which may not indicate an absence of consciousness (e.g., inattentional blindness) but rather an absence of memory (i.e., inattentional amnesia; Wolfe 1999). Prinz (2010) objected that in inattentional blindness studies, participants report seeing nothing, whereas in typical forgetting studies (e.g., Sperling 1960), participants do report seeing something but cannot report what it is. Even if the empirical effects do show genuine absence of consciousness, however, they at best demonstrate that attention is necessary in some instances but not that it is necessary in all instances, which (as explained above) is beyond empirical reach.

To show that attention is not necessary for consciousness, it is enough to find one instance in which attention is absent but consciousness is still present. van Boxtel et al. (2010) reviewed inattentional blindness studies in which participants were still conscious (i.e., not blind) of the gist of the unattended stimuli. This and other evidence has been criticized on the grounds that attention was not really absent in these studies or that consciousness was not really present (overestimated because of forced choice awareness measures; e.g., Prinz 2010). Another argument for the idea that attention is not necessary for consciousness comes from studies showing that attention and consciousness rely on separate neural pathways and are therefore part of separate systems. For instance, some authors have linked attention to a dorsal vision-for-action pathway and consciousness to a central vision-for-perception pathway (Milner & Goodale 1995, Vorberg et al. 2003). Reliance on different neural pathways indicates that attention and consciousness are different things, but it does not exclude dependence of one on the other (Tapia et al. 2013). Moreover, more recent accounts take it that both pathways are for action, the ventral pathway for action planning and the dorsal pathway for action adjustment, and that cross talk between them is crucial (Hommel 2010).

Sufficiency of attention for consciousness. Several theorists (e.g., Kouider & Dehaene 2007) subscribe to the view that attention is not sufficient for consciousness of a stimulus because other factors are necessary, such as certain levels of stimulus intensity and duration. This is obvious for some forms of attention but less so for other forms. Searching for a stimulus or directing one's attention to a location or a temporal window is not sufficient for becoming conscious of a stimulus; the stimulus also has to be present, which means that it has to have some duration and some intensity. Stimulus-based attention allocation, on the other hand, already presupposes the presence of a stimulus with some duration and intensity, which is why it is less obvious that this type of attention would not be sufficient for consciousness of the stimulus (for related arguments, see De Brigard & Prinz 2010).

To show that attention is sufficient for consciousness, one should show that in all instances in which attention is present, consciousness is present as well. Examining all instances in which attention is present is impossible. Standard empirical practice consists in accumulating evidence for instances in which both attention and consciousness are present and generalizing them to all other instances. Another strategy is searching for flaws in studies purporting to show that attention is not sufficient for consciousness (e.g., Prinz 2011).

To demonstrate that attention is not sufficient for consciousness, one should find one instance in which attention is present and consciousness is absent. A first line of evidence comes from studies in which manipulation of the direction of attention modulated unconscious processing. This has been shown for temporal (Kiefer & Brendel 2006), spatial (Kentridge et al. 2008; Sumner et al. 2006; Tapia et al. 2011, 2013), and feature-based attention (Kanai et al. 2006, Schmidt & Schmidt 2010, Spruyt et al. 2012, Tapia et al. 2010). In these studies, directing attention to the time window, location, and/or feature of a subliminal stimulus occasioned or improved processing of that stimulus, but not up to a point that the stimulus became conscious. Other findings show the modulating influence of the amount of available attention on unconscious processing (Martens & Kiefer 2009). For instance, Pessoa et al. (2002) reported that the manipulation of attention load led to more or less activity in subcortical structures, such as the amygdala, and this activity was taken as evidence of unconscious processing.

Another piece of evidence comes from studies in which unconscious stimuli influenced the spatial, feature-based, or stimulus-based direction of attention (see reviews by Mulckhuyse & Theeuwes 2010 and van Boxtel et al. 2010). For instance, Jiang et al. (2006) showed that participants directed their attention to subliminal pictures of male or female nudes depending on their sexual preference, thereby producing a spatial cuing effect: faster reaction times to targets preceded by a relevant unconscious nude cue than targets not preceded by such a cue.

The evidence reviewed in this section supports the ideas that (*a*) attention does influence consciousness, (*b*) attention is not necessary for all types of consciousness, and (*c*) attention is not sufficient for consciousness, given that other factors appear to be necessary in some instances.

From Consciousness to Goals

It is often assumed that implementation of the goal to engage in a process (as in control in the promoting sense) requires a conscious stimulus input (e.g., Shallice 1988) and that implementation of a counteracting goal (as in control in the counteracting sense) requires consciousness of the process (e.g., Dehaene & Naccache 2001). Several findings contradict these assumptions. A first line of research shows that conscious goals can be applied to unconscious input. Several studies report that a conscious promoting goal or task can be misapplied to unconscious stimuli (e.g., Ansorge & Neumann 2005, Kunde et al. 2003, Tapia et al. 2010). For instance, Van Opstal et al. (2010) found that same-different judgments of target pairs (numbers: 3-3) were also conducted on preceding masked prime pairs (letters: a-A). Martens et al. (2011) found that a conscious task set (e.g., perceptual versus semantic), independent of a specific task (e.g., press left for square and right for circle), influenced processing of unconscious stimuli. Other studies reported that conscious counteracting goals were successfully applied to unconscious processes operating on unconscious stimuli (e.g., Jáskowski et al. 2003). For instance, Verwijmeren et al. (2013) found that the conscious warning about subliminal advertising diminished its impact on subsequent choice behavior.

Representational quality: mental person factor subsuming intensity, duration, and distinctiveness of a representation

A second line of research shows that unconscious goals can be applied to conscious input. Lau & Passingham (2007; see also Mattler 2003) reported faster target responses when the instructed target task and an unconsciously primed target task were the same than when they were different (e.g., phonological versus semantic judgment). This makes the case for promoting goals. The case for counteracting goals is made by van Gaal et al. (2008, 2009), who found that a subliminal cue signaling the participant to stop responding (stop cue) or to refrain from responding (no-go cue) resulted in actual stopping or delayed responses. Although this line of research does not contradict the assumption that control requires a conscious input, it does show that unconscious control is possible (at least under certain conditions; Hassin 2013, Kiefer 2012, Kunde et al. 2012).

A handful of studies combine the features of both lines of research, demonstrating an impact of unconscious goals on unconscious input. Ric & Muller (2012) presented a masked instruction to add (versus represent) numbers, followed by two masked flanker numbers, again followed by a number or letter target. If the target was a number and corresponded to the sum of the flankers, classification of the target was facilitated, but only when the masked instruction was to add numbers.

In sum, the evidence reviewed above indicates that (*a*) implementation of a (conscious or unconscious) promoting goal does not require a conscious stimulus input, and (*b*) implementation of a counteracting goal does not require a conscious process.

Alternative Set of Relations Among Factors

Taken together, the empirical evidence reviewed above does not support the idea that goals, attention, and consciousness stand in a one-to-one relation. This goes against the perfect coherence view. The evidence suggests an alternative set of relations, convergent with several contemporary proposals (e.g., Cleeremans & Jiménez 2002, Kiefer 2012, Kouider & Dehaene 2007, Kunde et al. 2012, Pourtois et al. 2013). This alternative set of relations imposes a different way of thinking about automaticity and has important implications for the diagnosis of a process as automatic.

The starting point is the premise that all information processes require an input of sufficient quality. The nature of this input depends on the type of process considered. A first type of process takes the raw stimulus as its input and hence requires a stimulus of sufficient quality. Examples of first-type processes are the formation of a new stimulus representation and the activation of an already existing representation. (In the latter example, an additional condition is the existence and availability of the stimulus representation.) A second type of process takes a stimulus representation as its input and hence requires a stimulus representation with sufficient quality. Examples of second-type processes are the spreading of activation from the stimulus representation to associated representations and processes that use the stimulus representation in some other way. But what are stimulus quality and representational quality made out of? Stimulus quality subsumes

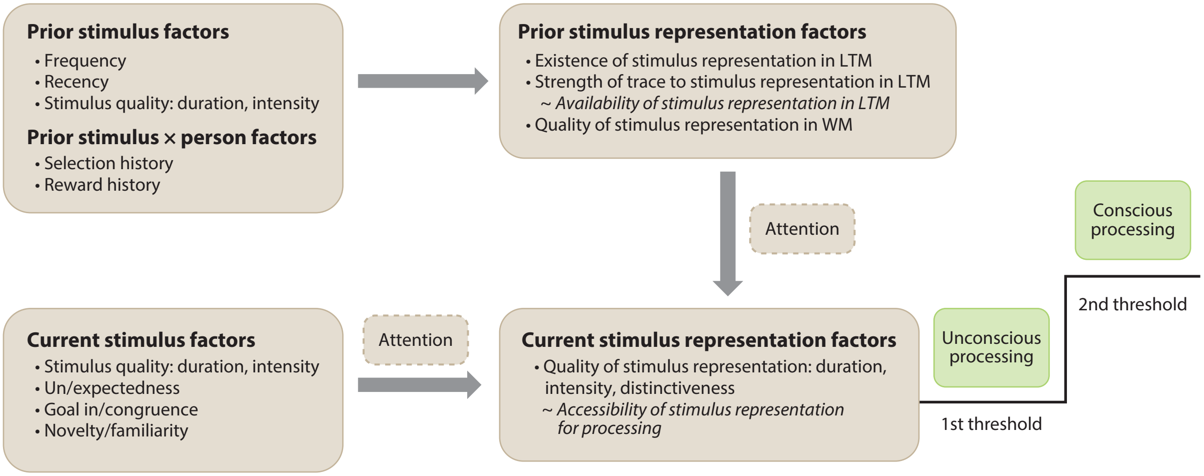

Figure 2

Factors hypothesized to influence representational quality.

factors such as stimulus intensity and duration. Representational quality subsumes factors such as the level and duration of its activation and possibly other factors such as distinctiveness (see Cleeremans & Jiménez 2002).

Representational quality can be influenced by various factors, which can be organized in the following sets: (*a*) current stimulus factors, both physical ones (e.g., stimulus quality subsuming stimulus intensity and duration) and mind-dependent ones (e.g., goal in/congruence, un/expectedness, and novelty/familiarity); (*b*) prior stimulus factors (e.g., frequency and recency) and prior stimulus × person factors (e.g., selection and reward history); (*c*) prior stimulus representation factors, such as the existence, availability, and quality of prior stimulus representations (goals, expectations, and mere representations); and (*d*) the amount and direction of attention. The current representational quality itself fits in a set that can be named current stimulus representation factors. It is closely tied to accessibility: High-quality representations are accessible for application in further processing and behavior (see **Figure 2**).

As to the relations between these sets, it may be hypothesized that prior stimulus (× person) factors (e.g., frequency, recency, selection history, and reward history) influence prior stimulus representation factors (e.g., the existence, availability, and quality of goals, expectations, and mere representations). These prior stimulus representation factors, in turn, may influence the quality of current stimulus representations, and so may current stimulus factors (e.g., intensity, duration, goal in/congruence, un/expectedness, novelty/familiarity). Attention has been hypothesized to either moderate (i.e., influence) or mediate (i.e., be necessary for) the latter two influences.

The picture drawn so far suggests that the factors influencing current representational quality are cumulative: If one of the factors is low, other factors may compensate so that the quality nevertheless reaches the threshold required to trigger processing. For instance, the short duration of a stimulus may be compensated by an increase in its intensity, the amount of attention directed to it, and/or the amount of preactivation from goals, expectations, or mere representations (or vice versa). Consciousness has a special status: Rather than being a primary codeterminant[6] of

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[6] Note that consciousness can be a secondary codeterminant of representational quality via recurrent processing.

representational quality, consciousness is better conceived of as the result of an additional increase in representational quality up to a second threshold. In other words, representational quality must reach a first threshold to allow for unconscious processing and a second threshold to allow for conscious processing (Cleeremans & Jiménez 2002). To elaborate on this picture, different types of (conscious and unconscious) processes (e.g., sensory versus semantic) may require somewhat different thresholds of representational quality, and it may also be fruitful to consider thresholds for access and maintenance in working memory and for transfer to long-term memory. The exact position of all these thresholds is an empirical matter, but the upshot is this: Some factors may be low (e.g., short stimulus duration) and others high (e.g., high amount of attention), but their summed influence on the representational quality may suffice to trigger unconscious or conscious processing. This is at odds with a perfect coherence view, which assumes that processes are either high on all factors or low on all factors (e.g., fast processes are also ones that are efficient and remain unconscious). The next sections review empirical evidence pertaining to (*a*) the influences of various factors on current representational quality, (*b*) the additivity of these influences, and (*c*) the increasing thresholds of representational quality from unconscious to conscious processes.

Factors Influencing Representational Quality

This section provides examples of empirical evidence for the influence of prior stimulus (× person) factors, prior stimulus representation factors, and current stimulus factors on the quality of the current stimulus representation, as well as evidence for the role of attention in these influences. The quality of a stimulus representation is inferred from (*a*) neural activity in regions known to code for the stimulus (or regions feeding into these) or (*b*) behavioral performance on various tasks thought to be mediated by representational quality.

Prior stimulus (× person) factors. The frequent and/or recent presentation of stimuli has been shown to improve processes and behavior based on these stimuli, as illustrated by increased priming effects due to repetition (Atas et al. 2013) and expertise (Kiesel et al. 2009), and the increased likelihood of using a frequently or recently presented adjective in a subsequent unrelated person judgment (Higgins 1996). An increase in current representational quality has been taken to be one of several mediators of this influence. A possible scenario is that the frequent presentation of a stimulus installs a stimulus representation (existence) and/or reinforces the memory trace leading to an existing one (availability). Each stimulus presentation also temporarily increases the quality of the representation. Thus, if a stimulus was recently presented, the representation of the stimulus has an increased quality, which allows (*a*) it to be accessed and applied in subsequent processing or (*b*) an additional presentation of the stimulus to benefit from the preactivation. On a neural level, recent functional magnetic resonance imaging studies (e.g., Müller et al. 2013) report that the repetition of initially novel, low-quality stimuli leads to an increase followed by a decrease in neural activity in regions coding for the stimuli (inverse U-shaped function). This has been taken to reflect the formation or optimizing of stimulus representations, starting with a strengthening phase and followed by a sharpening phase with more robust or more synchronous firing (Müller et al. 2013, Ranganath & Rainer 2003).

Prior stimulus representation factors. Prior stimulus representation factors include the existence, availability, and quality of prior stimulus representations, such as goals, expectations, and mere representations. Evidence for the influence of prior representation factors on current representational quality comes from studies in which the goal to respond to a stimulus feature (and probably also the expectation to encounter the feature) increased the baseline firing of neurons coding for that feature, even in the absence of a stimulus (e.g., Serences & Boynton 2007).

Current stimulus factors: physical and mind dependent. Evidence for an influence of physical stimulus factors on representational quality comes from psychophysical studies showing an influence of luminance, contrast, and stimulus duration on neural activity and priming effects (e.g., Kouider & Dehaene 2007, Schmidt et al. 2006, Tzur & Frost 2007).

Mind-dependent stimulus factors also influence representational quality. This is suggested by studies in which masked priming effects only occurred when the primes were part of an expected range of stimuli (Kiesel et al. 2006; see also Kiefer 2012). Other lines of research report that unexpected (abrupt) and novel stimuli boost their neural representations (e.g., Müller et al. 2013) with the help of neuromodulators (e.g., acetylcholine, noradrenaline, and dopamine) known to be involved in the recruitment of attention and the strengthening of memory traces (Lisman et al. 2011, Ranganath & Rainer 2003). Similar neural-boosting effects have been registered for valenced or goal-relevant stimuli (Cunningham & Zelazo 2007, Pourtois et al. 2013, Sander et al. 2003). Behavioral evidence for the influence of goal relevance on representational quality comes from studies showing that (subliminal and other) stimuli were better or only capable of producing certain effects when they were relevant for a goal or task [e.g., priming effects (Ansorge & Neumann 2005, Tapia et al. 2010) and implicit learning (Eitam & Higgins 2010, Hassin 2013, Kiefer 2012, Kunde et al. 2012)]. For instance, subliminal drink advertisements only affected consumption when participants were thirsty (Karremans et al. 2006).

One question that arises is how it is possible that both matches (e.g., goal-congruent, expected, and familiar stimuli) and mismatches (e.g., goal-incongruent, unexpected, and novel stimuli) with prior representations can increase the quality of current representations. A first piece of the puzzle is that matches can surf on the prior activation of the stimulus representation on which they subsist. If one wants, expects, or thinks about an apple, the representation of an apple is already active and the subsequent encounter with an apple (match) simply adds to this activation. This does not hold for mismatches, which suggests that a different (or additional) mechanism underlies their influence on current representational quality: Goal-incongruent, unexpected, and novel stimuli are all potentially goal relevant (Öhman 1992). This may induce a call on the entire system to recruit extra resources for boosting the stimulus representation (e.g., via attention; Eitam & Higgins 2010, Öhman 1992).

Attention. The idea that attention influences representational quality is inherent in the view that one of the functions of attention is to enhance, amplify, sensitize, or boost processing (e.g., Dehaene & Naccache 2001, Kiefer 2012, Pourtois et al. 2013). Selection, another cited function of attention, is not independent from enhancement. The representation of a stimulus that gets selected is relatively more enhanced than the representations of competing stimuli, although the absolute level of enhancement may vary greatly. Selection is related to the direction of attention, whereas enhancement is related to its quantity.

There is abundant evidence that attention driven by various sources (e.g., abrupt onsets, goals, and goal-relevant stimuli) influences representational quality; in other words, that attention moderates the influence of these sources on representational quality. Studies show that spatial attention driven by abrupt onsets and goals increases (or optimizes) neural activity and improves perceptual performance in contrast detection and selection tasks (see Carrasco 2011, Kiefer 2012). Similarly, feature-based attention increases the neural activity in cortical areas coding for those features and improves perceptual performance inside and outside the focus of attention (see Carrasco 2011, Maunsell & Treue 2006). Pourtois et al. (2013) reviewed evidence that attention driven by fearful faces (exemplifying threat value, arousal, negative valence, and/or goal relevance) enhances neural activity in areas coding for faces and improves low-level perceptual performance.

Stimulus onset asynchrony (SOA): time between the onsets of two stimuli (e.g., prime and mask)

Three remarks are in place. First, improved perceptual performance can rely on increased neural activity and/or increased external noise reduction (see Carrasco 2011), but both neural mechanisms may contribute to an increase in representational quality considered on a higher level of analysis (Pourtois et al. 2013). Second, Ling & Carrasco (2006) suggested an inverse U-shaped relation between attention and representational intensity, starting with enhancement and followed by adaptation after sustained attention. Third, some researchers (e.g., Pourtois et al. 2013) take increased neural activity in certain sensory areas as the neural signature of attention, thus blurring the distinction between attention and representational quality and perhaps even jeopardizing the viability of the attention concept altogether.

The studies listed above suggest a moderating role of attention. Another line of research has explicitly addressed the mediating role of attention; that is, whether attention is necessary for processing. This has been the topic of controversy between early and late selection models. Early models only allow the preattentive processing of simple sensory features (Broadbent 1958), whereas late models allow the entire meaning of stimuli to be processed before attention (Deutsch & Deutsch 1963). To demonstrate preattentive and hence attentionless processing of a feature (e.g., sensory, semantic, valence), one must show that the feature is processed (i.e., leakage of the feature through the attention filter) while attention to it is absent (i.e., no slippage of attention toward the feature; Lachter et al. 2004). Irrelevant feature tasks (e.g., priming, Stroop, and flanker) examine whether processing occurs of a feature that is irrelevant for the task and hence presumably not attended to. Another way to demonstrate attentionless processing of a feature is to show that the manipulation of attention (present versus absent) does not affect the quality or speed of this processing. In a spatial cuing task, for instance, a cue steers attention toward a location in which the target does or does not appear. If processing of the target is unaffected by whether it was validly or invalidly cued, it is taken to be independent of spatial attention. Evidence for the preattentive processing of semantic features with both methods is mixed (Lachter et al. 2004, McCann et al. 1992). Critics have argued that in these methods, focused or diffuse attention toward the irrelevant feature (in irrelevant-feature tasks) or uncued location (in cuing tasks) was not entirely prevented (e.g., because stimulus durations still allowed for covert attention shifts; Lachter et al. 2004) and was sometimes even encouraged (e.g., in tasks with unpredictable target locations, participants have to move attention across the entire perceptual field). Conversely, if attentional modulation of the effects does occur, this may indicate that processing of the feature of interest required attention, but it may also indicate that the influence of the feature on responding required attention (McCann et al. 1992, Moors et al. 2010). Finally, these studies can at best demonstrate that attention is necessary for processing in some instances, but not that attention is necessary overall.

Additivity of Factors Influencing Representational Quality

In the masked priming literature, the idea is pervasive that stimulus intensity, time, and attention influence the quality of the stimulus representation (as measured by the magnitude of the priming effect) in a compensatory manner (Kiefer et al. 2011, p. 61). Tzur & Frost (2007) parametrically manipulated luminance and stimulus onset asynchrony (SOA; time between prime onset and mask onset) and observed that an increase in luminance compensated for a decrease in SOA in determining the priming effect. In a study by Schmidt et al. (2006), the increase in priming with increasing SOA was steeper for high-contrast than low-contrast primes, which suggests an additive effect of contrast and SOA. A trade-off between attention and SOA is suggested by Bruchmann et al.'s (2011) finding that unattended stimuli with a long duration and that are unmasked can be conscious, whereas attended stimuli with a short duration and that are masked remain unconscious. Reynolds et al.'s (2000) observation that the contrast of unattended stimuli must be 50% higher than that of attended stimuli provides evidence for the additivity of attention and stimulus intensity. Using a spatial cuing task, Risko et al. (2011) found that repeated words suffered less from a lack of spatial attention than did nonrepeated words, supporting the idea that repetition and attention compensate each other. Some studies provide support for the additivity of different types of attention, such as spatial and feature-based attention (e.g., Hayden & Gallant 2009); attention driven by goals, abrupt onsets, and/or emotional faces (Brosch et al. 2011, Cave & Wolfe 1990); and attention directed to stimuli with a conjunction of features (e.g., horizontal and red; Andersen et al. 2008). In its most radical form, the additivity assumption takes it that no factor is necessary by itself but can be compensated by other factors. A weaker interpretation is that some factors can be compensated up to some point, but they cannot be entirely absent.

Increasing Thresholds of Representational Quality from Unconscious to Conscious Processing

The idea that the representational quality must be higher for conscious than for unconscious processing (Cleeremans & Jiménez 2002) is reflected in the use of backward masking to render stimuli unconscious. Backward masking reduces the exposure time and in this way presumably truncates the representational quality (Kouider & Dehaene 2007). Behavioral studies confirm that increasing the SOA between primes and masks increases the visibility of the primes (Charles et al. 2013, Lau & Passingham 2006, Vorberg et al. 2003). Neurophysiological studies report correlations between the strength of the neural responses evoked by a stimulus and conscious detection of the stimulus (e.g., Kouider et al. 2007, Macknik & Livingstone 1998, Mathewson et al. 2009, Moutoussis & Zeki 2002).

The idea that unconscious and conscious processes require different thresholds of representational quality does not imply that this is the only difference between both types of processes. Priming studies reporting (single and double) dissociations between priming effects (indicating prime processing) and masking effects (indicating prime consciousness) at the same SOA range have been explained by invoking various extra mechanisms: consolidation or working memory encoding (Kiefer et al. 2011), attention-mediated availability to working memory encoding (Prinz 2011), and recurrent processing (Lamme & Roelfsema 2000). This leaves us with two scenarios: Representational quality is only one among several conditions for consciousness, or the extra representational quality is what allows the extra mechanisms to kick in (Mathewson et al. 2009).

In conclusion, the empirical data reviewed resonate well with the view that unconscious and conscious processing must be fueled by external or internal factors and that several of these factors are interchangeable. The factors covered by the traditional automaticity concept (goals, attention, and time) do not have a special status in this respect. Before discussing the implications of this view for the diagnosis of processes as automatic, the review zooms in on the causal and mechanistic explanations of automaticity proposed in the literature.

CAUSAL AND MECHANISTIC EXPLANATIONS

A causal explanation of the automaticity of a process links the automaticity features of the process (explanandum) to causal factors (explanans). In other words, these are factors involved in the development toward automaticity, or short, automatization. Two major causal factors that have been identified are hard-wired makeup and practice, and they have served as a basis to distinguish two types of automatic processes. Hard-wired automatic processes come with a number of innate automaticity features. Learned automatic processes have acquired their position on several automaticity dichotomies as a result of practice (Treisman et al. 1992). Practice involves the repetition of the same procedure over the same stimuli (consistent data practice) or over varying stimuli (consistent procedure practice; Carlson & Lundy 1992). Consistent data practice increases the automaticity of processes tied to specific stimuli. Consistent procedure practice builds up the automaticity of processes independent of specific stimuli. Practice can range from a single repetition to a very elaborate number of repetitions (Spelke et al. 1976). Practice corresponds to the factor repetition or frequency, which has been hypothesized to exert its influence via the strengthening of representational quality. This hypothesis brings us to the territory of mechanistic explanations.

Rule-based process: mental process in which the output is produced by the application of a rule to an input

Associative process: mental process in which the output is produced by the activation of a memory trace leading to a previously stored output

A mechanistic explanation of the automaticity of a process specifies the subprocesses at lower levels of analysis responsible for automatization; that is, the transition of the process from a (more) nonautomatic to a (more) automatic state. Here, only learned automatic processes are considered because innate automatic ones are not supposed to make such a transition. There are two proposals for low-level processes involved in the automatization of processes. Logan (1988) proposed that the automatization of a high-level process (e.g., calculation) is based on a shift from the low-level process of algorithm computation (defined by Logan as multistep memory retrieval) to the low-level process of single-step memory retrieval. After sufficient repetition of the same chain of steps going from the same input to the same output, a direct association is formed between the input and the output, such that the presentation of the input alone directly activates the output. Anderson (1992; see also Tzelgov et al. 2000), however, proposed that the automatization of a high-level process can be based on the strengthening of algorithms or procedures, next to the strengthening of declarative facts. If the same procedure is repeatedly applied (on the same or different stimuli), it gets stored in procedural memory so that it can be directly retrieved and applied thereafter. If the stimuli also remain the same, input-output relations are formed as well and stored in declarative memory.

The distinction between single-step memory retrieval and algorithm-computation or procedure application is reminiscent of that between associative and rule-based processes in dual-process models of reasoning and decision making (Sloman 1996). These models typically follow Logan's (1988) view that nonautomatic (high-level) processes are based on (low-level) rule-based processes, whereas automatic (high-level) processes are based on (low-level) associative processes. It is notoriously difficult to conceptually and empirically distinguish between rule-based and associative processes (Hahn & Chater 1998, Moors 2014, Moors & De Houwer 2006b). For instance, both processes can explain generalization toward new stimuli (Smith & Lerner 1986). This complicates empirical research designed to test whether rule-based processes can be automatic in addition to associative ones (cf. Hélie et al. 2010). Despite these difficulties, Logan (1988) not only proposed to explain but also to define automaticity in terms of direct memory retrieval (automatic processes are ones based on direct memory retrieval). It could be argued that by doing this, he prematurely entered an insufficiently tested explanation of automaticity into the scientific definition of this phenomenon (see Bechtel 2008).

Another factor that has been mentioned as influencing automatization is the complexity of a process. Complexity refers to the number of steps that must be followed (vertical complexity) or the number of units of information that must be integrated at a single time (horizontal complexity). The received view is that simple but not complex processes can be automatic. This view is contradicted by recent studies showing that complex information integration can be fast, unintentional, and even unconscious (see reviews by Hassin 2013, Mudrik et al. 2014). For instance, Mudrik et al. (2011) used a continuous flash suppression method to keep pictures below the threshold of awareness. They found that pictures broke faster through the suppression when they depicted a mismatch between an object and the context (e.g., a watermelon in a basketball game) than when they did not (e.g., a basketball in a basketball game). This suggests that integration of the stimuli with their context occurred before they broke into consciousness. Other illustrations of unconscious information integration have been reported in decision research (e.g., Bechara et al. 1997), categorization (Hélie et al. 2010), similarity judgments (Van Opstal et al. 2010), and arithmetic (Ric & Muller 2012). Although several researchers now believe that some forms of information integration can occur unconsciously, they do think there are limits. Mudrik et al. (2014) argued that unconscious information integration is not possible for novel information and when the temporal and spatial distance between the to-be-integrated elements is too large. Other authors hold that rules can be applied to subliminal input only if the rule was set in advance (e.g., Kiefer 2012). Based on the additivity view defended here, it could be tested whether some of those limits may be shifted when other factors, such as the goal relevance of the stimuli, is increased (see Hassin 2013).

CONCLUSION

The research reviewed does not support the traditional view of perfect coherence between the ingredients of the most often mentioned features of non/automaticity: goals, attention, and consciousness. The evidence suggests an alternative picture in which the quality of the input determines processing, with the factors feeding into this quality capable of compensating each other, and with less quality needed for unconscious than conscious processing. Although the evidence reviewed here already goes some way in supporting these assumptions, future research is needed to test them in a more systematic way.

The alternative view has important implications for the diagnosis of the automaticity of specific processes (e.g., evaluation, decision making, and information integration). Given that automaticity is a gradual notion, conclusions about automaticity can at best be relative. Rather than studying whether a process is automatic, one can study whether it is more automatic than other ones. But this is not all. Building on the assumptions that every process requires an input of sufficient quality, and that several factors can contribute to this quality in a cumulative manner, comparing processes with regard to a single factor (e.g., amount of attention) is not very informative. For instance, if one process requires less attention than another one, this may be because the first has a more intense stimulus input, which compensates for the lack of attention. Proponents of the perfect coherence view sometimes argue that generalizing the conclusions of necessity and sufficiency reached in some instances to all other instances is an inference to the best explanation. This argument is jeopardized, however, if the instances in which evidence for necessity and sufficiency were obtained were ones in which compensating factors were absent or low. For instance, it is possible that in studies in which attention was found to be necessary for consciousness, other factors that could have contributed to the representational quality necessary for consciousness (e.g., prior goals, repetition) were low. Thus, if the aim is to compare the automaticity of two processes, it is best to map the network of factors required for both processes to operate, or alternatively, to compare the processes with regard to a single factor while keeping all other factors equal. This not only asks for a parametric approach, in which factors are gradually manipulated (Mudrik et al. 2014, Schmidt et al. 2011), but also for an approach in which the relations between several parametrically operationalized factors are outlined.

SUMMARY POINTS

1. Componential explanations of automaticity specify non/automaticity features such as un/conscious, un/intentional, non/efficient, and fast/slow as well as their interrelations.

2. Features of non/automaticity can be reframed as factors (e.g., goals, attention, time, consciousness) that influence the occurrence of processes. This opens the door for considering factors that are not traditionally included in the automaticity concept but that also influence the occurrence of processes.
3. Factors can be organized according to six independent axes: (*a*) procedural versus nonprocedural, (*b*) current versus prior, (*c*) person versus stimulus (and person × stimulus), (*d*) physical versus mental (and mind dependent), (*e*) absolute versus relative, and (*f*) occurrent versus dispositional. This taxonomy goes beyond the common top-down versus bottom-up dichotomy in several ways.
4. The view that there is perfect coherence among non/automaticity factors is challenged by empirical evidence against the assumptions that (*a*) goals are necessary and sufficient for attention, (*b*) attention is necessary and sufficient for consciousness, and (*c*) consciousness is necessary and sufficient for goals.
5. Evidence is reviewed in support of the alternative view that (*a*) most of the listed factors influence the quality of representations (which form the input of many processes), (*b*) they do so in an additive way (such that the lack of one factor can be compensated by the excess of another factor), and (*c*) a first threshold of this quality is required for unconscious processing and a second threshold for conscious processing.
6. Factors influencing representational quality (which is itself a current representation factor) can be organized into current stimulus factors, prior stimulus factors, and prior representation factors. Attention may be considered as a mediator or moderator of some of these influences.
7. Processes cannot be diagnosed as automatic or nonautomatic but rather as more or less automatic than other processes. However, given the additivity assumption, comparing two processes according to a single feature or factor of automaticity is not very informative, unless all other factors are kept equal. If this is not possible, it is best to map the entire network of factors required for both processes to operate.
8. Causal explanations of automaticity specify factors involved in automatization such as repetition and complexity, and mechanistic explanations specify low-level processes underlying automatization, such as direct memory retrieval and the strengthening of procedures.

FUTURE EFFORTS

Instead of comparing processes with regard to the entire network of factors they require to operate, the focus may be shifted to comparing processes with regard to the amount of representational quality they require. Future efforts may concentrate on ways to measure representational quality.

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