University of North Carolina Asheville
Journal of Undergraduate Research
Asheville, North Carolina
May 2019

Scripts and Schemas: Differentiating Categories in Neuroimaging Research

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Abstract

Schemas are associational networks used in memory, predictions of event outcomes, and cognitive tasks that have theoretical significance in many different fields of psychology. Historically, as the concept of schemas spread to various disciplines and became applied to more and more topics, the definition of what a schema is and what properties schemas are supposed to have started becoming very broad. Such imprecision can lead to generalizability issues in neuroimaging studies wherein one attempts to identify what parts of the brain are used to process schemas. This paper aims to critically evaluate and compare research examining different kinds of schema, such as social scripts or hierarchical categories, and identify any meaningful differences between different types of schema. Data suggests that social scripts and hierarchical schemas may use overlapping but non-identical cortical networks, but too little research has been done under similar conditions to draw strong conclusions. A set of five behavioral criteria are proposed for use to clearly define schemas and their application by participants in an experiment. These criteria include properties schema have consistently demonstrated in behavioral research: A predisposition towards remembering schema congruent events and information; a tendency to interpret ambiguous stimuli in schema congruent ways; the ability to accommodate new schema-relevant information into a schema faster than learning new schema-independent information; a tendency to generalize pre-existing schema onto new stimuli that resemble the characteristics that define members of the schema; and the ability to change between different active schemas that describe the same features based on contextual cues. The importance of expanding neurological research into other less researched categories of schema is also addressed.

1. Introduction

Schemas were first introduced into psychology by the developmental psychologist Jean Piaget[1]. He used the term somewhat broadly, referring to the way that adults and children form associations and connect independent but related information into larger coherent systems of knowledge that could be applied in the future. His definition was a useful term for describing certain forms of knowledge, but it was not the kind of concrete functional definition that is conducive to careful research of the cognitive process itself. Schemas were developed into a form more like their modern usage by Frederic Bartlett[2], who placed attention on the role of schemas in the reconstruction of memory. Bartlett's work provided the basis for a wide range of research, mainly in the fields of social and cognitive psychology, that further refined the concept over the course of the 20th century.

Scripts are a somewhat more recent concept, seeking to explain how people understand common expected behavior and sequences of events. Similar to schema, they have been defined and experimentally operationalized from varying degrees of specificity ranging from incredibly broad to extremely precise. During a boom of schema research in the 1980s where the concept of schemas was applied to a wide variety of topics, scripts became regarded as a subset of schemas and continue to be treated as a form of schema in schema related research.[3] Despite this, there is still much ongoing script research that does not draw on schema-based theories[4].

After a lull in research since the 1980s, schemas have more recently begun to receive a lot of research attention again, this time from the field of neuroscience. Numerous studies are attempting to identify what parts of the brain are used to process schemas, what kind of activity that entails, and how schemas fit into established neurological functions ranging from memory to comprehension of text or body language and many other topics[5]. One of the great strengths of this research is the wide variety of different modalities and definitions that schemas have been researched under, allowing for consistent findings to illustrate just how many different contexts and topics that schemas are involved in. One of the great weaknesses of the current body of research is how little attention that important differences in how schemas are operationalized for experiments and what meaningful differences might exist between different subsets of schema, such as scripts or self-schema. In other words, commonalities between different forms of schema have been investigated and generally validated, but the differences between forms have been ignored.

Too little attention to these factors could result in serious assumptions being made about how different kinds of schemas work. For example, a major study in 2015[5] tested subjects by training them with a set of hierarchical categories regarding how fast fictional creatures were in relation to each other, and found evidence that the dorsolateral prefrontal cortex plays a key role in processing schema incongruent information, that subverts established schema knowledge. Despite the lack of any research since then that replicated that finding with scripts, this study is routinely cited by script-based schema studies which treat the applicability of this study to other types of schema as a given[3,6].

A related but independent issue is in regards to how things are determined to be schematic processes in the first place. In current behavioral schema research, the question of what kinds of thinking, reasoning, and learning actually use schemas and what merely looks like it might is a question that is very much still being explored[7]. In neuroimaging research, much less effort is placed into affirming that the experimental tasks actually involve schema in the way that they are believed to. This would be perfectly fine if schemas were well-defined and this research was using established and well-studied tasks that were known to call on schema in established ways. Instead, the definition of what is a schema is still vague and varied. This causes yet more problems for generalizability across studies. It is not safe to assume that results from a study about how people make sense of the plot to a movie they have not seen before are applicable when people are making sense of a familiar script; the pre-existing schema that is present in the latter case is not present in the former, and the studies that have touched on schema formation strongly suggest that it takes multiple instances of exposure to a novel stimulus in order for a schema regarding it to actually develop[5,7].

It is for these reasons that more precise definitions for schemas and schema subtypes are needed. The first part of this paper will go over testable features that are typically ascribed to schemas, experimental results that validated or refuted those features, and conclude with a set of testable criteria the determine whether an experimental task involves schematic processing. The second part will examine scripts and "object schemas" (schemas related to non-event objects) as two possible subtypes of schema, and explore similarities and differences between the neurological functioning of the two that can be gleaned from research thus far. The third section will examine self-schemas and stereotypes, two proposed types of schema that have not received attention in neuroimaging research yet, and discuss possible reasons they may or may not qualify as schema categories. Finally, the ramifications of this definitional system and the new avenues of research it suggests will be discussed.

2. A Functional Definition of Schemas

As originally defined by Bartlett[2] schemas are pre-existing information networks that influence and structure memory recall, especially when details are not clearly remembered. In theory, they are used in memory as a kind of reconstructive blueprint that allows for the assumption that things matched the schema unless otherwise noted by normal memory. Past research has validated this theory thus far with two effects: memories are more likely to be remembered accurately if the details match the schema, and false details are likely to be mistakenly incorporated into the memory if they fit the schema more closely than the real events did[8].

But memories are not the only domain that schemas relate to, and are studied under. Other theorists have argued that schemas also influence people's expectations of event outcomes, and how they interpret ambiguous situations[9]. If a schema seems to apply to a situation, people will expect the outcome to match that which the schema would predict (for instance, expecting a creature that your schema suggests is faster to win in a race) and if an ambiguous stimuli is presented that could match a schema, people will assume that it matches the schema (such as assuming someone is the protagonist of a film because they are played by the most famous actor that appears in it). These features have also been consistently validated behaviorally[8,9,10,11] and even linked by lesion studies[12,13] to brain regions that are also involved in schematic memory functions, suggesting that a common mechanism of some form is in play.

Another key element of schemas is their flexibility. Schemas change over time[2] and individuals can switch between multiple different applicable schemas based on context and priming[2,9,14,15]. New information that is incorporated into a pre-existing schema will be learned faster than new information that is learned in isolation[11]. Whereas contextual variations often occur as a consequence of having a great deal of experience with the subject matter. For example, someone living in America would likely have a script for eating at a restaurant that includes tipping the waiter at the end. If this person travels to Japan and offends the waiter when they try to tip them, it will be incongruent with their restaurant script. After spending time in Japan and learning that tipping is not done in that country (among various other differences in the Japanese restaurant script) the individual will develop an alternative script for Japanese restaurants that exists parallel to the one they used for American ones, applying a different script based on the context of what country the restaurant they are eating at is in.

This capacity to develop multiple similar schema and discriminate between different situations that require different schemas is not the only way in which schemas show a great deal of flexibility. In a process sometimes referred to as accommodation, individual schemas can change in response to sufficient incongruent information. As an example from a categorical schema, most people find penguins and ostriches to be highly incongruous with the larger category of birds when they first encounter them. But after sufficient interaction with flightless birds, an individual will adjust their schema for birds to no longer assume that all birds can fly. Depending on the frequency of interaction the individual may instead develop a "general" bird schema and secondary "flightless" bird schema, but if flightless birds become common enough in relation to the individual's experiences with flying birds, it may actually result in a change to the default schema applied to the concept of "bird" without other qualifying contextual factors.

Another aspect of accommodation that is often put forward is that new information can be incorporated into a pre-existing schema faster than it can be learned if there is no pre-existing schema. Part of this is common sense; you can't learn what a flightless bird is as easily if you don't even know what a bird is to begin with. But another part seems to have something to do with having a pre-existing conceptual network to integrate something into. Schemas seem to involve more parts of the brain assisting in memory than participate in most other forms of memory, so it's possible that this results in faster acquisition. Regardless of the cause, this is one of the key behavioral findings that separate schemas from other forms of memory and care should be made to test that this phenomena is in fact occurring under experimental conditions when one is performing a study to explain why it happens.

Schemas do not describe individual objects or sets of specific individuals. They are generally applied across an entire category, and are used to make sense of encounters with new things that have common features with a pre-existing schema. As such, they tend to generalize onto new stimuli that fit a schema, for better or worse. One example of this working well is when someone sees a parrot for the first time; even though the parrot is a new creature they have never identified before, the person will likely see it as a bird due to common features with other birds, and will assume that the parrot has other features in common with birds that they have not yet observed the parrot to engage in. On the other hand, generalization of schematic information is also why our hypothetical tourist might make the mistake of tipping at a restaurant in Japan: despite encountering a new establishment in a new part of the world, people frequently assume that their prior knowledge of that class of thing is still applicable unless stated otherwise[2].

Another feature of schemas that has often been touted is that people find schema congruent stimuli inherently more pleasurable than schema incongruent stimuli[16]. Theoretical bases for this being that it should take fewer mental resources to process a schema congruent stimulus, and that the subversion of expectations involved in a schema incongruent stimulus is likely to be disconcerting or at least confusing. However, the results from empirical research on this aspect of schemas has been mixed[17,18,19] and suggests a much more complicated relationship between incongruency and experience of pleasure, displeasure, and emotional states. Pending further research that explores this relationship more deeply in a wider variety of situations, it is likely unsafe to treat this as a known, established feature of schemas.

This leaves the known properties that schemas (as opposed to other forms of knowledge) possess: (1) Congruent recall: a predisposition towards remembering schema congruent events and information. (2) Congruent interpretation: a tendency to interpret ambiguous stimuli in schema congruent ways. (3) Accommodation: the ability to accommodate new schema-relevant information into a schema faster than learning new schema-independent information. (4) Generalization: a tendency to generalize pre-existing schema onto new stimuli that resemble the characteristics that define members of the schema. And finally (5) context sensitivity: the ability to change between different active schemas that describe the same things based on contextual cues.

Obviously, testing all five of these as part of or as preparation for any given neuroimaging study is going to be impractical. To some degree, precedence on what to test for should be based on what conditions the schema is being studied under. For instance, when studying activity during recall or encoding of schema related information, criteria 1 and 3 would be most relevant. In a schema-application task where memory is not being looked at as directly, criteria 2 and 4 would be more relevant and convenient to test for. Criteria 5 may be the hardest to test under laboratory

conditions, as laboratory conditions themselves form a context that will likely influence how schemas are applied and selected by participants. It is also the most dependent on the past experiences of research subjects in most cases, as the existence of multiple contextual schema for the same class of objects or events relies on a level of familiarity with various conditions for those things beyond that which the mere existence of a schema would require.

That said, in an ideal environment you could test all 5 systematically. Using the naturalistic schema of people walking dogs as an example, you could test for congruent interpretation by presenting subjects with a stylized picture of a person with a quadruped at the end of a leash, and asking them what kind of animal they think it is (subjects would be expected to interpret it as a dog, because dogs are what people typically take on walks using leashes). Generalization could then be tested by showing a picture of a man walking a cat on a leash while carrying a plastic bag and asking what the bag is for (subjects from American cities would be expected to assume the bag is for cleaning up poop, as is done when walking a dog). Congruent recall could be tested by showing subjects a series of videos featuring people walking dogs and asking them to estimate how frequently the dogs and dog-walkers engaged in various expected behaviors (schema-congruent behaviors should be estimated to be more common than they actually were in the selection of videos). Accommodation could be tested by asking subjects to either memorize dog-walking etiquette from a fictional country ("in Gorp, they typically hold the leash in their left hand") or to memorize similar meaningless information about fictional customs ("In Gorp, the national sport is gashomp") (the expectation would be that the schema-relevant dog-walking etiquette would be easier to remember than the disconnected un-facts). Context sensitivity could be tested in the aftermath of testing accommodation, by showing subjects another series of dog-walking videos and asking them to distinguish between which ones were typical or atypical, while some videos are marked as American and other are marked as Gorpian (subjects should seamlessly apply different standards to determine what is considered typical for each country without explicit instructions to do so). Similar kinds of tests could be used on laboratory-induced schemas as well, although the order of testing would likely change; congruent recall, congruent interpretation, and context sensitivity rely on a somewhat developed and established schema, whereas accommodation and generalization seem to contribute to the formation of new schemas in the first place and could be studied during the process of schema formation. In fact, studying exactly how developed a newly induced schema needs to be before various criteria begin to accurately describe it could be a fruitful avenue for future research.

3. Object Schemas vs Scripts

As mentioned previously, event-oriented scripts are typically regarded as a form of schema in schema research. The other most common type of schema used in research does not have a formal name in the same sense, but is concerned with the classification of objects and living creatures rather than sequences of events. Interestingly, these "object schemas" seem to have been more popular in schema-related lesion studies[12,13] but comparably much less common in fMRI studies. As such, less information is available about precisely what forms of activation occur during encoding, retrieval, and recognition of object schemas compared to scripts. On the other hand, Brod, Lindenberger, Werkle-Bergner, & Shing's landmark study[5] identifying the role of the dorsolateral prefrontal cortex (dlPFC) in processing incongruent events used events that were congruent or incongruent with an object schema, concerning which fictional creatures were faster than one another.

This means that while most of our information about what brain regions are active while schemas are being processed is derived from script based research, one of the key findings in the field has not been replicated using the scripts that are more commonly used in the research. This makes a direct, neurologically based validation of the classification of scripts and object schemas as being the same or similar neurological processes difficult. The current research provides enough information to glean hints about what may be similar or different, but nothing more.

To begin with, it is important to clarify that all 5 behavioral criteria apply to both kinds of schema. Various studies have found evidence for the 5 criteria as applied to object schemas: Information about parts of a cell is learned faster (criterion 3: accommodation) and remembered better (criterion 1: congruent recall) if the subject has a pre-existing schema for that information[11]. Students are told a guest lecturer is cold will interpret his behavior as being more cold[9] (criterion 2: interpretation of ambiguous stimuli). Subjects who are given descriptions of the members of a country club will interpret characters with similar characteristics as being members of the same club[10] (criterion 4: generalization). Subjects who are memorizing negative evaluative terms (creating a context of negative evaluations) are more likely to evaluate others negatively[14] (criterion 5: context sensitivity). Similar findings have been made with scripts: Subjects are more likely to remember actors behaving in a schema-congruent way in a scene than in an incongruent way[8] (criterion 1: congruent recall). Children are capable of making on the fly changes to a behavioral script when it proves situationally inappropriate (criterion 5: context sensitivity) and adapting these new variations as

forms of the script in the future[20] (criteria 3 and 4: accommodation and generalization). Optimistic individuals are more likely to make positive interpretations of negative events than pessimistic ones[21] (criterion 2: interpretation of ambiguous stimuli).

Based on the definition used in this paper, both object schemas and scripts qualify as schemas in the broader behavioral sense whether or not they have identical neurological underpinnings. That said, any such differences could lend key insights into how events are processed differently from other forms of information, which could have significant repercussions for learning and memory of event-based scripts. Such differences could also place the relevance of a great deal of script-based research into jeopardy, in so far as it relates to object schema.

One thing that has been made quite clear so far is that the ventromedial prefrontal cortex (vmPFC) and the medial prefrontal cortex (mPFC) are of critical importance to both. A number of lesion studies with patients who had suffered damage to their vmPFC showed that it was critical to object schemas in both memory[12] and application[13]. fMRI studies have also clearly indicated the importance of the region in both forms of schema[3,5,22].

Returning to the dorsolateral prefrontal cortex, no study that replicates Brod et al. with script based schema has been performed as of yet. This leaves the applicability of that finding to script based schema as somewhat unclear thus far. Pending more careful research, there is little that can be understood with clarity. The hints we have so far are mixed, however. One study that used scrambled event sequences as an incongruent condition found a decrease in activity in the mPFC compared to a coherently ordered script, but no increase in activity in the dlPFC[3]. Conversely, an older script-based study[23] that used an experimental task that more closely resembled Brod's (subjects had to discriminate between congruent and incongruent events) did find elevated activity in the dlPFC during that task which could be a sign that it serves a similar role, but the use of older, poorer quality fMRI and the lack of discrimination between activity during schema-congruent and schema-incongruent tasks makes it very hard to use that study as anything more than a hint for directions of future research. Possible explanations for the lack of dlPFC activation in the more recent study include that congruent events that happen out of sequence produce a kind of "temporal incongruence" that is not processed the same way as events that are themselves schema incongruent by nature, or that the dlPFC activation occurred as some part of the process of discriminating between congruent and incongruent events rather than simply trying to make sense of incongruent events. As it stands, the additional complexities introduced by the temporal sequence component of a script needs to be examined more closely in order to avoid any properties that are unique to temporally ordered scripts being mistaken for universal properties of schemas.

Although the mPFC and vmPFC have received by far the most attention in schema research for good reason, there are other regions that appear to be involved nonetheless. Brod et al. and Baldassano, Hasson, and Norman both identified a large number of peripheral areas that also seemed to be involved in schematic functions, for an object schema and a script respectively. These studies do not make a perfect comparison as Brod looked at brain areas that were active in successful recall of congruent or incongruent outcomes, whereas Baldassano identified brain areas that had unique patterns of activation which could be used to identify which of two different scripts the subject was currently being exposed to. Keeping in mind that these are not a perfectly comparable studies, there is nonetheless a great deal of overlap in which parts of the brain are active in what on the surface appears to be two very different tasks: recalling the results of fictional races, and watching or listening to stories about people eating or going through an airport. Also worth noting is that the areas of overlap (mPFC, superior frontal gyrus, and posterior medial cortex) are all parts of the default mode network. Conversely, there were a great deal of areas outside the default mode network that were only implicated in one study or the other, such as the superior temporal sulcus having script-distinguishing activity in Baldassano's study whereas in Brod's study the middle and inferior temporal gyri were active for successful recall of congruent and incongruent outcomes, respectively.

The evidence supporting scripts and object schemas as belonging to the same closely related class of mental process cannot be overstated. In urging for greater distinctions to be made between the two concepts the goal is not to treat them as completely different things, but rather to emphasize the fact that those differences that do exist might be important. It is still unknown what if any role the dlPFC plays in scripts. It is still unknown if the activity of the superior temporal sulcus is unique to scripts or was simply missed by Brod's methods, and what it might be doing for scripts that it does not do for object schema if it is in fact unique. Without making distinctions and doing replications with different kinds of schemas, meaningful distinctions will be missed or forgotten.

4. Other Classes of Schema: Self-Schema and Stereotypes

4.1 Self-Schema

Object schema and scripts may be the most researched categories of schema in neuroscience today, but they are not the only categories of note that have emerged in the behavioral literature. Two other such categories are self-schemas, which are schemas that describe and influence the behavior and self-image of the subject, and stereotypes, a type of object schema that describes classes of people. Both of these are topics that could have a great deal of social importance if they become better understood on a neurological level.

Self-schemas were initially proposed by Hazel Markus[24], whose initial study provided evidence for criteria 1 (congruent recall) and 3 (accommodation). More recent research has developed evidence for criterion 5 (context sensitivity), showing that people can and do have multiple different self-schema, most blatantly as a consequence of multicultural backgrounds[15]. Criteria 2 and 4 (congruent interpretation and generalization) may simply not be appropriate for describing self-schemas; it is unclear exactly how someone could be made to interpret ambiguity in their own behavior, and it is equally unclear what someone would generalize a schema onto if the schema is specifically relevant to themselves. Indeed, by virtue of describing a specific individual rather than a class of things, a self-schema is something of an exception to the normal "blueprint" for a schema.

If that is the case, why describe the self as a schema? First, there is the simple answer that all of the behavioral criteria that could apply are accurate, suggesting that there may be a great deal of similarity between how self-schema and other kinds of schema work. Second, the narrowness of the schema is partially explained by the relationship between familiarity and schema specification. Any given person is more familiar with themselves than with anything else, as every waking moment is spent in their own presence and filtered through their own thoughts and feelings. It is somewhat logical to suppose that people would develop schemas about themselves that are far more specific than for most other things, developing a wide variety of subtly different self-schemas that are applied in different circumstances.

Finally, there is tantalizing neurological evidence that there may be something in common. Self-reflective thought is distinctly characterized by activity in the mPFC, just like schematic processing[25]. The posterior medial cortex has also been implicated in some forms of self-reflective thought[26], extending the neurological overlap of self-reflection with schematic processing from merely being overlap in a single critical region to being a shared collection of closely interlinked brain regions within the default mode network.

This is certainly not conclusive evidence that self-schemas are the same thing as other schemas. But there is not conclusive evidence that object schemas and scripts are exactly the same, either. What the evidence does suggest is that there may be some very crucial features in common, and that future research on the relationship between self-perception and schemas might lead not only to a deeper understanding of what a schema is and how a schema forms, but also to a deeper understanding of the neurological underpinnings of identity itself.

4.1 Stereotypes

Stereotypes have been studied under the purview of schemas in the past, and meet most if not all of the five criteria proposed here[27]. In many ways, they can be thought of as a subset of object schema, which apply to classes of people rather than other sorts of creatures or things. Stereotypes are here discussed as a meaningful category of schema for future study, not because they have a mixture of large distinctions and clear connections, like the self-schema, but instead are suggested for future research because of the broad social implications that they have.

Understanding more deeply how stereotyping works and how it can emerge naturally from the same kind of knowledge structures that people normally use for anything else could help inform efforts to counteract them. With a better understanding of how stereotypes can change, it would be possible to develop empirically based interventions to try to alleviate harmful stereotypes. With more knowledge of how they form and how problematic elements integrate into stereotype schema in the first place, it might be possible to help prevent them from forming in such a way anyway.

The schema model is particular value because if it can be established that stereotypes really are functionally identical to object schema, it would allow a great deal of research to be performed using innocuous schema that could then be used to inform understandings of stereotypes and stereotype change. This is important because possession of negative stereotypes is increasingly frowned upon in today's society, giving participants a motivation to lie and not report on what their stereotypes actually are in ways that are unlikely to occur in studies of schemas that are neither embarrassing

nor politically charged. There is also the possibility that making participants confront and analyze their own negative racial or ethnic stereotypes could cause them distress that could be spared by using other schemas as a stand in. On top of these reasons, there is also the fact that experimentally inducing a stereotype schema (like Brod did with an object schema in his study[5]) would be rather unethical, but the formation of stereotypes could be studied in the lab by using other topics for schema.

All of these research possibilities hinge on stereotypes being functionally identical to other types of schema, or at least object schema. This is not a safe assumption to make until further research is done. It may become apparent that stereotypes are more resistant to change in some ways than other schema, or that they form slightly differently. They may not even be based in the same underlying neurological processes at all. Although stereotypes are often classified as a form of schema, fMRI research on prejudice and stereotyping has been mixed, mainly focusing on the role of the amygdala although regions of the prefrontal cortex have been implicated for stereotyping[28]. Research using conditions and methods that more closely match those typically used in schema research would be needed in order to more carefully investigate similarities.

These are far from the only categories of schema that could be meaningful for neuroscience research. Even if the mechanics of the schema structures themselves are the same, any idiosyncrasies of how the subject matter of the schema is processed ordinarily will likely influence the schema in some ways. There is already data showing that basic scripts have unique patterns of activation that can be used to distinguish each other, even if they cover broadly similar parts of the brain[3]. Indeed, if every schema were the same within the brain then every schema would be functionally identical in content and application. Even small and subtle differences can become meaningful during real-world application of research findings. The more precise our knowledge of schemas, the more effective that knowledge will be in informing effective approaches in fields as diverse as education, social justice, advertising, and many more.

5. Discussion

In many ways this paper proved more of a collection of ways in which more research is needed than anything capable of forming a coherent theory or model for schema classification. The data that would be needed to clearly delineate the distinctions between object schema and scripts on a neurological level does not quite exist yet, only inconsistencies and absent replications that leave it ambiguous how much of the difference is caused by differing experimental methods as opposed to any concrete conclusions. It does however paint a picture as to what kinds of research need to be done in order for these questions to be answered.

A replication of Brod's study with script based schema would be invaluable. Subjects could be trained on a number of variations on a script for some novel activity, such as a fictional card game or a celebration for a fictional holiday. After doing a number of manipulation checks based on the 5 criteria proposed in section 2, subjects would be asked placed in an fMRI to memorize a number of renditions of the script and report on whether they were expected or unexpected variations. Not only could a comparison between congruent and incongruent instances reveal whether the dlPFC is still involved in incongruent stimuli, but the presence or absence of activation in other regions that differed between studies of various schema categories would help clarify what difference were caused by the experimental tasks, and what differences were caused by the content of the experimental tasks.

Similar research could be performed using stereotypes and other variations on schema. Self-schemas provide a special issue for this kind of research however. It will likely prove difficult to induce a fictional self-schema in a subject for instance, and even if such a thing could be done ethically at all it would be very unlikely to be as complex and personally relevant as naturalistic self-schemas. Comparisons of how self-schemas function in relation to other schemas may require new methods to be developed for studying self-schemas and then applied to other kinds of schema to create a point of comparison, rather than using methods designed for object or script schema to measure self-schemas.

During this research, the five criteria proposed in section 2 can act as a measuring stick. In studies where a novel schema is induced, selected criteria can be tested as a form of manipulation check to ensure that the induced schema is in fact a schema. In research on naturalistic schema, they can instead be used as a preliminary check to determine whether the schema of interest has typical properties.

That said, these criteria are far from perfect. Much like how Mandler's schema congruence theory has been complicated by more recent research[18,19], rigorous testing of these criteria may well turn up results that they are less universal or more complex than they are stated here. This possibility is not a flaw in the schema criteria, but in fact an intentional element of their design. In order to adequately confirm whether these criteria hold up universally or simply in the conditions that they are traditionally tested under, they need to be measured in a wide variety of circumstances.

Testing these criteria in more studies will allow not only for confirmation of schematic activity via multiple measures (behavioral and neurological) but it will also increase the odds of discovering exceptions, abnormalities, and special cases in how schemas work.

Another potential flaw of this set of criteria is simply that with as many different definitions of schema as have been produced, it is a near certainty that not all schema ever studied or described will qualify as schema under these criteria. The intent of these criteria is not in fact to disregard or discredit other conceptions of what schemas are, such as the criteria developed by Ghost and Gilboa[29]. Rather, they are intended to complement other systems of defining schema by giving testable behavioral criteria based in measurable effects of schema usage. The goal is to provide a common point of measurement to confirm whether or not different studies that are investigating schemas are actually studying the same psychological events. This requires a set of criteria general enough that several different things can qualify, but specific enough that not all forms of learning will display those traits. Only time will tell for sure if these criteria actually hold up in the long run. Schemas have a long history of evolving meaning and changing definitions, and in all likelihood this set of precision-oriented criteria will only be another step in a never ending sequence of refinement and change, as the definition of schema develops and incorporates new information just as schemas themselves do.

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