

SENSORIMOTOR SCHEMA(S)

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Synonyms

Infant habitual action; enactive or action schemas

Definition

Within constructivist theories the sensorimotor schema is held to be the principal unit of knowledge in use during infancy. A sensorimotor schema is a psychological construct which gathers together the perceptions and associated actions involved in the performance of one of the habitual behaviors in the infant's repertoire. The schema represents knowledge generalized from all the experiences of that behavior. It includes knowledge about the context in which the behavior was performed as well as expectations about the effects. Sensorimotor schemas are central to Jean Piaget's explanation of infant development.

Theoretical Background

The development of the psychological construct known as the sensorimotor schema has its origins primarily in the work of Jean Piaget and in particular in his books on sensorimotor development (Piaget 1936; Piaget 1937). Sensorimotor schemas are a special case of the more general notion of schemas. Like schemas they are knowledge structures which represent the generic knowledge abstracted from a number of experiences in a similar situation. Sensorimotor schemas are simply those schemas which are in use during the sensorimotor period (from birth to roughly the end of the second year). A typical example of a sensorimotor schema is the schema of shaking a rattle. This schema gathers together the visual and tactile perceptions of the rattle, as well as the motor actions involved in the shaking, and the expectation of visual and auditory perceptions during the execution of the action. Because it is generic, the same schema could be said to operate in the infant's interactions with a class of objects which are broadly similar to the rattle, and where the infant's action is broadly similar. If the infant is presented with a new object, and the infant seems to treat it like the rattle, shaking it in a similar way, then Piaget would say this new object had been *assimilated* to the schema of the rattle. If the rattle-schema is adjusted to account for slight differences in this new object, then Piaget would say the rattle-schema had *accommodated* to the new object. If the accommodation is significant, then Piaget would say that the schema had been *differentiated* to produce a new schema appropriate to the new situation. In other situations it may be that two independent schemas are found to be closely correlated, and become

combined as a new (higher-level) schema. In this way Piaget describes the whole of infant development from the perspective of the operation of sensorimotor schemas. In comparison with the schemas in use in adults, sensorimotor schemas tend to be less abstract and more directly tied to the actions, objects, and contexts in the infant's experiences. Nevertheless, there are major differences in the types of schemas in use at the start of the sensorimotor period and at its end, with a clear progression towards more abstract and higher-level schemas.

Piaget defined six sequential stages during sensorimotor development (Piaget, 1936), with a qualitative difference between the sensorimotor schemas in use in each stage. The first of these stages is the reflex stage (roughly the first month) where the reflex actions such as sucking and grasping, and papillary and palpebral reactions to light are exercised. Each of these actions is associated with its own global schema which generalizes from experiences where the action happens, and gradually learns to recognize the situations where the action is triggered, and the expectation of what sensory impressions arise while the action is in progress. Furthermore, different modes of operation become recognized, for example the difference between sucking the nipple for feeding, or sucking the fingers.

The second stage (roughly from one to four months) begins with schemas which arise from the fortuitous discovery of the results of actions on the infant's own body, for example the schema of sucking the thumb. Piaget identifies these schemas with what J. M. Baldwin has called the *circular reactions*. In this stage schemas are also formed which integrate different modalities, for example auditory, tactile and visual. By the end of this stage a schema for reaching for, and grasping, seen objects has been formed.

During the third stage (roughly from four to eight months) it is again a case of repeating results fortuitously discovered, but these schemas are now of a higher order because they act on objects in the environment. Piaget calls these the *secondary circular reactions*. A typical example of a schema discovered at this stage is that of pulling a string to shake a rattle. Note that the infant at this stage is incapable of understanding the connection between the string and rattle, and will not be capable of discriminating, in advance, situations where the string is connected or not connected. This schema is a global ensemble, incorporating parts whose connection is not fully understood. During this stage there is a rapid growth in the number of schemas in the infant's repertoire, as new schemas are differentiated from previous ones in order to repeat interesting discoveries. Example actions include squeezing, shaking, striking, scraping, rubbing, and pulling.

During the fourth stage (roughly from eight to twelve months) intentional *means-end* sequences of actions are performed. For example, the infant will intentionally displace an obstacle in order to retrieve a desirable object which is visible behind it. In this type of situation two distinct sensorimotor schemas can be distinguished; one for the *means* action which displaces the obstacle, and one for the *end*, which is to grab the desired object. The schema of the *end* is able to subordinate the *means* schema, and to direct its operation. This implies that the sensorimotor schemas must now incorporate relatively advanced knowledge of the world, because the effect of an action on an object is understood, and also on the relationships between

objects (for example the relationship “in front”). In contrast to the previous stage, at this stage the schemas can be combined in new situations, and are not confined to the situations where the combination was discovered fortuitously. For this reason Piaget refers to these as *mobile* schemas.

During the fifth stage (roughly from twelve to eighteen months) schemas become experimental; they are not only repeated, but are intentionally varied so that the relationships between initial conditions and effects can be studied. Piaget calls these schemas *tertiary circular reactions*. This new experimental ability can now be employed to generate new means schemas when the infant’s existing repertoire does not happen to have the appropriate means schema. An example of this is the effort to retrieve an out-of-reach object with a stick; even if the infant does not have schemas for performing the appropriate actions to displace the object, the required schemas can be discovered through experimental groping.

The sixth stage (roughly from eighteen to twenty four months) could be said to not properly belong to the sensorimotor period, because there is significant evidence of internal representation of objects, actions, and effects. This gives rise to covert planning, where rather than groping in the world, the infant carries out the necessary experimentation mentally, and then exhibits a complete correct sequence of actions. This has been achieved by internalization of the sensorimotor schemas acquired previously.

Through all this progression there is a gradual increase in the abstractness and objectiveness of the sensorimotor schemas; while the earliest schemas capture a very subjective knowledge locked in particular contexts, the later schemas have abstracted away from these contexts and capture knowledge about relationships between objects and actions in the world. In this development schemas are a tool for learning, because their effort to repeat and assimilate events leads them to generalize and gradually embody more abstract information about the world.

The term “sensorimotor schema” is not widely used in contemporary psychological research. Piaget’s theory paints a picture of a very close coupling between the development of perceptual competences and action competences, and even representation and reasoning, with each being built up in tandem by the same process. For this reason the idea of a sensorimotor schema which combined all elements made sense as the unit of knowledge. A classic example is in the case of the means-end action of retrieving a hidden object. Piaget held that it was through experiences with acting on objects in relationships such as “in front” that the perceptual competence and representational competence to understand about hidden objects was constructed. Later research has suggested that perceptual and representational competence may be more independent from action competence (Bremner 1994), and that in most cases perceptual competence precedes action competence, but in some cases the reverse may be true (Kellman and Arterberry 1998). Although a consensus has not yet been reached on many details, the general picture emerging is considerably more complex than Piaget’s account, and the sensorimotor schema may be at too coarse a level for its proper description.

Important Scientific Research and Open Questions

Since Piaget's early work on infancy new experimental methods have been developed to probe infants' knowledge of the world, most notably the infant habituation method, and the violation of expectation paradigm. This measures infants' looking times to determine if the event displayed to them violates their expectations. This method has been used to determine such things as knowledge that objects continue to exist while occluded. This work has uncovered a curious gap between the advanced knowledge which infants seem to demonstrate by looking, and the relatively impoverished knowledge that seems to be available to them when they are required to act. There is considerable controversy about many of these results, and especially their interpretation, with some scientists contradicting them outright (Cohen and Cashon 2003).

Neuroscientific evidence suggests that there are in fact two parallel processing streams for objects; the ventral or "what" stream, and the dorsal or "action" stream. The fact that there might be multiple partial object representations (Mareschal et al. 2007), independent of a particular behavior, suggests the need for a much more fine grained unit of organization than Piaget's sensorimotor schema; although there must be cells integrating this sensory and motor information, these cells must be integrating relatively sophisticated fragments, rather than building up the knowledge from scratch as in Piaget's theory.

Within Artificial Intelligence there have been some efforts to computationally model sensorimotor schemas; this requires a representation to capture schema knowledge. There is a consensus in a number of works that a schema should be a three-part structure with an initial state description, and action, and a predicted resulting state description. There are also ongoing efforts to define algorithms which can exhibit cognitive development by building higher level schemas out of lower level ones (for example, Chaput 2004).

Many questions about sensorimotor schemas remain to be answered. For example, is the sensorimotor schema really a useful concept to serve as a generic knowledge structure, or is it maybe an approximation for great diversity of different things which only seem to share similar features from a "zoomed out" view, but may turn out to be quite different on closer inspection. Similarly, it is not known if sensorimotor schemas really do share a common structure with later more abstract adult schemas (as suggested by Piaget) and if they are reusing the same machinery in the brain, or if on closer inspection they may be quite different.

Cross-References

- Schema(s)
- Infant learning and development
- Schema Activation
- Schema Construction
- Schema Development

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Definitions

Accommodation: In cognitive and developmental psychology this theoretical term refers to the process by which existing mental structures and behaviors are modified to adapt to new experiences. Beyond this, accommodation may also refer to the physical process by which the eyes increase their optical power to focus on an object as it draws near.

Assimilation: This term is used differently in various disciplines. For instance, in biology “assimilation” refers to the incorporation or conversion of nutrients into protoplasm. In linguistics it refers to the change of a sound in speech so that it becomes identical with or similar to another, neighbouring sound. In psychology, “assimilation” refers to the process of responding to new facts and situations in accordance with what is already known and retrievable from memory. In terms of Piaget’s epistemology, assimilation and accommodation are the two complementary processes of the adaptation of intelligent systems to their environments.

Differentiation: The process by which a schema can be split into two new schemas. This happens when a schema attempts to assimilate a situation which requires considerable adjustment of the schema. The result is the generation of a new schema which is more appropriate to the new situation, while the old schema is refined (made more specific) so that it no longer assimilates the new situation.

Experimentation: The process of actively and intentionally varying the performance of a known action or behavioural sequence in order to discover new variations which may yield interesting results. This activity is driven by an intrinsic motivation to discover new things, and broadens the learner’s repertoire, thus improving the ability to solve future problems.