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LEARNING AND COGNITION – ISSUES AND CONCEPTS

Contents
Attention in Cognition and Early Learning
Concept Learning
Cooperative Learning
Intelligence
Learning from Multiple Information Sources
Memory
Metacognition
Personal Epistemology in Education: Concepts, Issues, and Implications
Piaget: Recent Work
The Adult Development of Cognition and Learning
Vygotsky and Recent Developments

Attention in Cognition and Early Learning

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“From a psychological view, attention includes changes from sleepiness to high alertness, from focused OR to a single object to unfocused awareness of the general scene, from responsiveness to external event to responses driven by the achievement of a particular goal.”
(Posner and Rothbart, 2007a: 16)

A child’s ability to direct his or her attention drives awareness; only objects and events attended to will enter the child’s mind. In this sense, attention processes are essential for learning and cognitive development. Attention influences and is, in turn, influenced by various brain systems, an interaction that creates priorities affecting both perception and action. Thus, alertness and the way attention regulates, or is regulated by brain functions become highly relevant for all domains of learning. Without attention it becomes difficult, if not impossible, to take in new and important information. We, adults and children, are active in selecting what to attend to and what to ignore – a process that becomes more and more voluntary during development.

The view of an infant as passive, incapable of communicating and remembering, and unaware about self and others has changed radically during the last 50 years. Typically, developing infants have a sensory system, which makes them capable of perceiving and interacting with the environment promoting communication, emotional exchange, and signals for caretaking. In addition to this sensory system, they use their own body as a vehicle, not only for exploration of themselves, that is, building sensory motor schemas, but also for assembling information about other individuals. To learn from and understand other people and socially relate to them is crucial for a healthy development. Therefore infants’ face processing is seen as an early indicator of this social attending. Newborns prefer face-like patterns suggesting an innate mechanism favored in brain processing. Furthermore, by 4 months infants look longer if there is a mutual eye gaze with the adult compared to averted eye gaze. Also, auditory perception in 6-month-old infants is linked to sensitive detection of human voices, such as discrimination of phoneme segments, both in native and foreign languages. However, at the age of 12 months this ability declines showing that early on our brain is prepared for a general language acquisition, but that exposure to one language with its specific prosodic and phonetic patterns reduces this capacity.

Attention in Infancy

All sensory systems are functional at or before birth and of these, the visual system is probably both the best-understood and least-mature system. It is actually a difficult
task for the newborn infant to respond to visual stimuli. When a newborn infant acts on complex visual information, as evident when the neonate imitates facial movements, the infant responds in spite of the fact of the immaturity of the visual system. Jerky eye movements make it hard to control vision and it is difficult for the immature system to capture fast-moving objects. In short, the infant’s control of fixation is mostly not under voluntary control at birth and, during the first months of life, infants cannot resist being drawn to certain patterns. Visually, the newborn infant is attracted to high spatial frequencies (e.g., checkerboard pattern and edges), to slowly moving objects (moving stimuli are more attractive than static ones), and to face-like patterns. The attraction to edges provides necessary input for the visual cortex to develop (input helps to organize cell columns in visual cortex) while the attraction to face-like patterns guides the infant toward the social world.

All nonvisual sensory systems are also functional at birth but their role in early attentional processes is less well studied, although auditory attention probably is as important as vision for early development. Hearing is essential both for language learning and for making the social world interesting. The newborn infant recognizes human voices at birth (in fact, a fetus can learn to identify the mother’s voice several weeks post-partum) and the melody of the mother’s voice is identified within the first weeks. The human voice, especially the female voice, attracts the infants’ attention both to the social world and to language.

Selective Attention

Selective attention develops rapidly over the first months of life. The newborn infant has less oculomotor control, less control over attentional shifts, and is attracted by salient details in perceptual displays. A neonate is not able to understand a partly occluded object as a unity and reacts only to direct visible information. It becomes a very difficult task if the neonate must identify a center-occluded object – the infant sees only the top and the bottom part of the object – in order to solve a task. This does not imply that a newborn child is not able to take in the relevant information, only that during the first months of life, perception and attention is more driven by environmental input (exogenous processes) coupled with biologically driven subcortical processes. Slowly, vision becomes more and more cortically controlled, acuity develops, the visual field increases, the eyes become better coordinated and inspection times decrease. A shift is usually seen around 2–3 months making the infant more visually competent when inspecting new objects, and, maybe most important, the child now becomes able to partake in prolonged face-to-face interactions with the caregiver.

The problem with perceptual completion, to see an object as a whole in spite of the fact that it is partly occluded, also changes during the first months of life. Some capacity is observable already at 2 months but it is not until 4–5 months that the ability to solve perceptual-completion problems can be expected to be robust. Interestingly, children at 3 months seem to be in a transition phase. A recent study (Amos and Johnson, 2006) identified two groups of children, perceivers and non-perceivers: the children who were able to perceive unity (i.e., they solved the perception-completion task) used a more efficient strategy when solving a visual search task. These differences may stem from the possibility that the two groups reflect different stages in early brain development. Selective attention makes it possible for the child to become an active participant in his/her development and early differences in this ability might have an impact on later cognitive development.

The capacity to attend selectively is also related to disengagement, an ability that develops rapidly over the first months of life. As depicted in Figure 1, infants younger than 2 months tend to focus on one stimulus at a time. If a second stimulus is added to the visual display while the first stimulus is still visible, the infant is more or less unable to make a gaze shift. However, by 3–4 months, this is no longer a problem.

Selective looking and habituation have dominated research on infant attention. Generally, the length of looking declines during infancy, especially from 3 to 4 months and onward. Younger infants need longer inspection time (familiarization) than older infants; studies indicate a negative correlation between visual recognition and the inspection time needed. Selective attention has also been used to study auditory attention (e.g., the ability to discriminate between specific sound signals or between mother’s voice and a stranger’s voice).

Phases of Attention

Behavioral Phases

Attention in infancy is usually described as made up of three or four distinct phases representing different underlying processes (see Figure 2): The first phase, AR (AR), reflects the physiological readiness of the organism to react to any stimuli. Usually AR varies from deep sleep to active wakefulness through several intermediate phases. A characteristic of the young infant is that state changes occur often and rapidly, which affects the manner in which early attention is modulated. Without adequate AR, no attention can take place. During the second phase, usually called orienting (OR) or selective attention, the infant’s attention is directed toward specific stimuli, that is, an interesting event is identified and the system becomes prepared for further inspection. Sustained attention (SA), phase three, reflects a phase of active information processing or encoding. SA is often described as a voluntary
process and it has been linked to anterior brain systems. The final phase of attention, attention termination (AT), on the other hand, is linked to disengagement processes reflecting continuous looking after cessation of any active information processing. AT has been proposed to reflect the posterior brain system identified by Posner and colleagues and the disengagement processes have been observed to be a stronger prediction of recognition than sustained attention, at least for static stimuli.

**Attention: Brain Networks**

A recent attempt by Posner and Rothbart (2007b) to integrate behavioral studies of attention with current findings within cognitive neuroscience identifies three neural networks that underlie central aspects of attention: orient, alert, and executive attention.

Alerting signifies that the child is in a state of readiness for reacting to new incoming stimuli. From a biological point of view, alerting has been linked to subcortical processes (thalamus) as well as to right parietal and right frontal areas. Norepinephrine is the main neurochemical modulator.

Orienting means that attention aligns with incoming sensory signals and that some information is selected. It is activated by posterior parts of the brain, mostly the parietal lobe (e.g., the superior parietal lobe) but also some frontal (frontal eye fields) and subcortical areas.
Executive attention indicates the ability to monitor responses, thoughts, and feelings, processes that not only involve mainly anterior brain areas (frontal cortex) but also some parts of the basal ganglia. It is hypothesized that executive attention plays an important role in the ability of the developing self to regulate positive and negative affect. Dopamine is the main neurochemical modulator.

The more posterior parts of the attentional system develop relatively early. Thus, the young infant is more able to alert and orient than to show executive attention, although it takes time for these systems to become fully mature as well. The first signs of the executive system can be noted toward the end of the first year, but it will take 8–10 years for it to reach adult-like levels.

All three networks – especially the executive network – are essential for the infant to develop an ability to display effortful control, that is, to self-regulate one’s own behavior.

Aspects of Attention

Novelty

Novel objects and novel locations affect attention from birth although the parallel process of familiarity also exerts a strong influence on attention during the first months of life. Behaviorally, novelty preference can be reliably observed from approximately 4–6 months of age. Identification of new information leads to faster and more reliable OR, activates the alerting system, recruits available relevant brain resources (working memory and sustained attention), and prepares the system to encode a new file (transfer information to long-term memory).

The identification of a new object is governed by two processes. The first process to emerge is the ability to identify a new location. This ability is related to the control of eye movements and is, in some form, present at birth. It is observable through inhibition of return (IOR), which means that the visual system resists going back to a previous location; new locations are more attractive. The second process, the identification of a new object, is a slower-developing visual skill. It is usually established by 4–6 months and is related to the development of object recognition. This ability is observable through visual recognition memory.

Visual Recognition Memory

From 3 to 4 months and onward, the infant’s ability to process new information has proved to be robust. This can be shown in paired-comparison experiments or tests when the child’s preferential looking pattern is observed. Typically, a child prefers new information (a novel stimulus) in comparison with familiar information, which makes it possible for the researcher to calculate a novelty preference score. This score provides an index of the child’s visual recognition memory, because the child has to remember the familiar target in order to show a preference for the novel one. Measures of novelty preference/visual recognition memory in early infancy have been found to be a significant predictor of later intelligence quotient (IQ) as well as of nonverbal communication and language (e.g., Colombo, 1993; Bornstein and Sigman, 1986). As an example, it has been reported that visual recognition memory measured in infancy predicts receptive language at 3 years even when controlling for general IQ. These results suggest that attentional and memory capacities tapped by visual recognition memory as measured by novelty preference are important for later developing communication skills.

Visual recognition memory seems to tap into the very basic functions of our nervous system but exactly how these early attentional and memory processes affect later cognitive processes are still unexplained. One clue to an explanation has been proposed by Colombo and collaborators who found that, at 4 months, attention termination explained more of the observed variance in a novelty recognition task than sustained attention. The research group interprets their findings as supporting the “hypothesis that individual differences in the disengagement underlie the relation between look duration and cognitive performance in early to mid infancy” (Colombo et al., 2001: 1605).

Face Processing

Human infants show a preference for faces right from birth, a tendency that seems to be especially strong for moving face-like stimuli (Johnson, 2005). This has been interpreted by some as indicating a pre-wired system molded by evolution. Such a system is described as being controlled by subcortical parts of the visual system functional at birth making the face a highly salient stimulus for the newborn. Thus, the child is endowed with an in-built perceptual attention grabber for faces. Although the propensity for faces among newborns is not debated, the mechanism is. In a series of studies, Simion and co-workers have provided support for an alternative view. They argue that the infant is not born with a pre-wired schematic configuration for faces but with a “domain-general bias towards configurations with more elements in the upper than lower half (i.e., top-heavy patterns)” (e.g., Cassia et al., 2004: 379). The conflict between these two contrasting views is not resolved; we still do not know exactly how to describe the mechanism responsible for making newborn babies especially attracted to the human face.
Furthermore, observations also suggest that infants are better at processing female than male faces, a finding that probably stems from the fact that infants have much more experience in processing female faces. However, conclusive studies addressing this interpretation are still lacking. Finally, over the course of the first year, infants begin to process naturally looking faces in the same fashion as adults do; that is, they analyze faces in a holistic gestalt-like fashion. While 4-month-old children focus more on internal facial features, 10-month-old children use a holistic strategy. Children at 6 months seem to be in a transition phase using both strategies.

Attention and Learning

The Directed-Attention Model

Memory span of objects is around one item at 6 months and two to three items at 1 year. This means that infant learning and infants’ complex social responses are carried out with a memory and attention system that is very limited compared to older children and adults. A model for how this can be achieved has been proposed by Reid and Striano (2007) who outlines a five-stage directed-attention model of infant social cognition. The model describes five perceptual stages that infants typically will master within the first year of life. The model is tentative but provides an ambitious attempt to integrate known perceptual and cognitive abilities and skills with the amazing social competence seen in the human infant. In brief, the proposed stages or phases are:

1. Detection of socially relevant organisms. Infants are born with a nervous system that directs them toward the social world. They are sensitive to distinctions between animate and inanimate objects, they prefer moving stimuli to static, biological motion to nonbiological motion, they are sensitive to the human voice, to rhythm, and they imitate (mimic) facial gestures.

2. Identification of socially relevant organism. The process to differentiate individual persons starts immediately at birth. The newborn infant rapidly learns to identify the mother’s voice, smell, and face. More complex responses, such as imitation, are also used early on (from 6 weeks) to identify persons.

3. Assessment of the locus of attention. Once the socially relevant organism has been detected infants start to “attend towards characteristic that index the locus of attention of the observed organism” (Reid and Striano, 2007: 105). Eye and head movements provide important information to the infant in early social interactions. The infant’s predisposition to enter into the social interactions with the caregiver is probably driven by intrinsic and biologically based motives to communicate with other humans.

4. Detection of object-oriented attention. Already at 4 months infants can use an adult’s gaze to learn about objects and, by 8–9 months, objects become parts of highly motivating joint-attention encounters. Objects or an aspect of the environment that has been highlighted through joint attention with an adult will become more salient to the infant who will direct more of his or her attention to those objects/areas. The first sign of an emerging declarative memory is observed at 6 months through the child’s ability to act on a memorized representation after a delay (deferred imitation).

5. Inference of goals and/or prepare response. Toward the end of the first year, infants begin to respond differently to accidental and intentional action. The child now starts to understand that people have goals that motivate their actions. The capacity of working memory increases, which makes it possible for the child to hold more than one piece of information online simultaneously.

Dyadic Attention

The interaction between a parent and the infant is characterized by rhythm, intimacy, and emotional exchange, the so-called proto-conversations. This interaction is encouraged by the mother through smiles and increased gaze in such a way that the interaction is prolonged and infants are active partners in this interaction, creating turn-taking sequences. Both mother and infant are sensitive to the contingency and quality of this interaction and have already created expectancies of specific patterns of communication from each other. This is evidenced by using still-face conditions where mother is either not responding to infant’s communication or by using double-video-technique showing pre-recorded interaction creating unsynchronized turn-taking from both partners. Furthermore, infants very early learn to anticipate, not only contingent communicative patterns, but also contingent behavior from their mothers. When infants’ distress is accompanied by parents soothing, the association between AR, parents’ response, and subsequent relief is easily learned – soothing is anticipated by the infant already at 4 months of age.

This intrinsic communication with human beings could not be enhanced without the infant exploring the physical environment. With an increasing ability of motor control, the child will experiment with its own actions on objects such as mobiles and thereby develop an early understanding of agency according to physical cause and effect. With the growth of contingent perception, the infant is able to accompany this physical agency into detection of cause and effect/reciprocity with partners into further developed nonverbal turn-taking sequences – both vocal and with objects (like pushing a ball back and
forth). This means that infants are able to coordinate their attention with another person and understand the framework in which communication takes place between two persons.

**Triadic Attention/Joint Attention**

Nine-month-old infants begin to understand that actors are pursuing goals and they combine the awareness of outside objects, events, and persons in order to share and coordinate their attention or perception of goal activities, the so-called joint attention. By performing joint activities such as building a tower of bricks or rolling a ball back and forth, the infants understand the concept of sharing goals. This is accompanied by attention skills such as following the other persons’ eye-gaze or pointing in order to direct others’ attention to objects in the surrounding, or trying to modify a persons’ behavior with gestures.

Attention skills that are initiated by the child (e.g., pointing) develop slightly later than behaviors that are responses to others (e.g., gaze-following). The capacity to direct another persons’ gaze to objects by the infants' own interest develops between 9 and 12 months and infants can use the pointing gesture for different purposes, for both sharing attention and requesting.

It has been argued that declarative pointing, in contrast to imperative pointing, relies on the understanding of others as mental agents and is driven by a motivation to share attention and interest with other persons; it has therefore been suggested to be especially difficult. In typically developing infants, the motivation to share attention and interest is probably strong and declarative gestures are common, in contrast to children with social impairments like autism. Experiment with 12-month-olds has revealed that the social context is crucial for the amount of points the infant makes. Only when the adult was active in sharing the infants’ attention to the event the infant pointed at, the infants’ pointing increased. The interpretation of this result was that the infant did not only want to direct the adult's attention, but also wanted to share this attention.

It has been shown in several studies that the capacity for joint attention is an important precursor to later-developing language and cognitive skills. Together with early memory measures (e.g., visual recognition memory and deferred imitation) joint attention probably lays the ground for later-emerging social cognition including intentional understanding.

**Understanding Intentions**

Humans are special in their capacity to understand others’ intentions. This is obvious when children pass false-belief tasks when they are about 4 years old. It can be argued that infants, by the time they begin to follow and direct others attention, have acquired some understanding of others as intentional agents and that other people act on the basis of their own view of the world.

From 6 months of age, infants follow another person's gaze to objects in the surrounding environment but they have been shown to pay more attention to where the head is turning, while older infants pay more attention to the eyes indicating understanding of the adult’s intentions. When adults turn to an object with their eyes open or closed it was observed that infants by the age of 12 months looked at the target if the adult turned to it with open eyes but did not do so if the person turned to it with eyes closed.

Furthermore, studies have revealed that infants in their second year understand the intention behind an action and not only the action they actually have seen; when 18-month-old infants were observing an action that the adult failed to perform they did not imitate the failure, instead they performed the complete action. Another evidence for early intentional understanding is that 9-month-old infants show anger and distress toward an adult who is unwilling to give them a toy, but not to an adult who is unable to do it.

**Compensatory Systems and Plasticity**

Questions have been raised whether the sensory system can compensate for a deficit in one area, since it is striking how blind people can use auditory and tactile cues for orienting themselves and getting information. In one study, it was shown that spatial tuning of tactile attention is more accurate in early blind compared to sighted individuals when areas for Braille reading are stimulated, suggesting a compensatory scaffolding for individuals who have experienced visual deprivation from birth or early infancy. The plasticity of the brain making it possible to overcome deficits may be underlined by the fact that the sensory systems work together, especially, according to the dimensions of space, time, and intensity. This so-called redundant, amodal information is seen as a cornerstone of perceptual development, for example, when an adult takes a child's hands and uses them for clapping, auditory, visual, and tactile systems are involved, discerning both rhythm and rate to the child.

**Conclusion**

With increasing age, looking and attention come more and more under voluntary control. The child becomes more able to decide what to focus on; he or she will, by 4–5 years of age, be able to choose to attend to information even if it is boring. However, attention never becomes completely voluntary. Processes like novelty preference and habituation influence attention throughout life.
In the future, knowledge might be increased by detecting specific genes influencing attention, maybe even specific genes for each network or various attentional processes (see Posner et al., 2007). This might help us gain a better understanding of how attention develops, how experience and biology co-act to create alertness and sustained attention, or the ability to initiate attention in another person – knowledge that will also be highly relevant for children with known disabilities such as ADHD or autism spectrum disorders.

See also: Cognition and Emotion; First Language Acquisition; Neuroscience Bases of Learning.

Bibliography


Further Reading


