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USING EYE-TRACKING METHODS IN INFANT MEMORY RESEARCH

BEBEKLERİN HAFIZA ÇALIŞMALARINDA GÖZ İZLEME YÖNTEMLERİNİN KULLANILMASI

Ayşegül Özkan[1*]

Abstract

Eye-tracking systems have improved as a direct consequence of technological developments, particularly since the 2000s, related to the smartphone industry. In psychology research, such systems have been used to investigate human cognitive processes based on the fact that the eyes work in conjunction with the central nervous system, thus the direction of the eyes can be used to provide information about the brain's cognitive process. This current review explains eye-tracking methodology linked to eye movements, to evaluate eye-tracker systems in terms of their advantages and disadvantages, and then discusses using eye-tracking methods in psychology and neuroscience researches, specifically focused on eye-tracking used on infants' memory studies using eye-tracking. The methodologies of these studies are compared to determine how a particular eye-tracking method may be useful for infant memory research.

Keywords: eye-tracking, infant memory, eye-tracking methods

Özet

Göz izleme sistemleri, özellikle 2000'li yıllardan beri akıllı telefon endüstrisi ile ilgili teknolojik ilerlemelerin doğrudan bir sonucu olarak gelişmiştir. Psikoloji araştırmalarında, bu tür sistemler, gözlerin merkezi sinir sistemi ile bağlantılı olarak çalışması esasına dayandığı için insan bilişsel süreçlerini araştırmak amacıyla kullanılmıştır. Böylece gözlerin yönü, beynin bilişsel süreci hakkında bilgi sağlamak için kullanılabilir. Bu derleme, göz hareketleri ile bağlantılı göz izleme metodolojisini açıklamakta, göz takip sistemlerini avantaj ve dezavantajları açısından değerlendirmekte ve daha sonra özellikle bebeklerde kullanılan göz takibine odaklanan psikoloji ve nörobilim araştırmalarında göz izleme yöntemlerini tartışmaktadır. Bu çalışmaların metodolojileri, belirli bir göz izleme yönteminin bebeklerin hafıza araştırmalarında nasıl yararlı olabileceğini belirlemek için karşılaştırılmıştır.

Anahtar Kelime: *göz izleme, bebek hafızası, göz izleme yöntemleri*

[1] MSc Brain Imaging, Department of Psychology, University of Nottingham, England
[*]Corresponding Author: Aysegül Özkan, Adress: 45 Lower Road, Beeston, NG9 2GT Nottingham, England, E-mail: aysegulozkan92@gmail.com, Tel: +447491806633

1. Introduction

1.1. The History of Eye Movement

With the incremental improvement of eye-tracking and recording technology since the 1970s there has been an incremental increase in studies of eye movements to examine cognitive processes. Earlier research was classified by Rayner (1978) into three periods, the first of which (c. 1870 to 1920) involved rudimentary observations of eye movement while reading (Huey, 1908). Approaches related to behavioural psychology dominated the second period from 1920 to 1970, but more possibilities were opened up during the third period from 1970 onwards due to the great improvement of recording systems' accuracy, associated with the integration of computers and eye movement systems (Rayner, 1978).

1.2. Earlier Eye- Tracking Systems

Eye movements are observed using eye-tracking systems that use various techniques to analyse the gaze direction of the eyes by following the change of eye positions (Poole & Ball, 2006). Eye-tracker devices yield data of utility to numerous areas such as psychology, marketing and human-computer interaction. Several different ways to monitor eye movements were developed from the 1950s onwards (Holmqvist et al., 2011):

1.2.1. Lense systems: From 1950 to 1970, contact lenses providing high precision were used with mirrors. Even if they were very uncomfortable, they enabled more detailed recording of eye movement that traditional observations.

1.2.2. Electromagnetic coil system: Silicon contact lenses were used to measure electromagnetic induction. These lenses were designed individually for each subject and applied on the anaesthetized eye. For this reason usage was uncomfortable, although it was accepted as the most precise method. This technique is known as electromagnetic coil systems.

1.2.3. Electrooculography (EOG) system: This system measures electromagnetic changes in the eye muscles when the eyeball is moved. It is still used as a low-cost eye-tracking technique for high frequency sampling, but it can only measure horizontal eyeball, movements and can be affected electromagnetic variations of another muscles.

1.2.4. Dual Purkinje system: This technique measures eye movements with video recording from the first and fourth Purkinje corneal reflections. Although it is very expensive and considers small visual recording areas, it provides highly precise and accurate data without any invasive procedures.

Eye-tracking devices are beginning to take more place in our lives with the development of technology so that eye-tracker producers have started to manufacture low-cost and flexible devices, such as those described below (Holmqvist et al., 2011; Dalmaijer, 2014):

• EyeLink 1000 was designed with two different options usage as head supported (chin or forehead rest) or head free. Accurate and highly precise data can be obtained, but head movement was more restricted than in other systems.

• EyeLink II is a head-mounted camera system and for precise eye measurement that can provide flexible head movement compared to EyeLink 1000. Accuracy depends on eye tracker shifting related to head movement.

• Static eye-trackers such as functional magnetic resonance eye tracker and primate eye-trackers based on fixed stimulus according to eye camera and the subject's head, as well as EyeLink 1000 and EyeLink II.

• Tobii has a computer screen with remote cameras and hidden illuminators, for bright-pupil tracking with high resolution, and it can also capture the view from the larger (i.e. whole surface) area of participants' eyes. In order to produce lighting and reflection from participant's eyes, Near Infra Red Light Emitting Diodes are used (Rele & Duchowski, 2005).

• Smart Eye Pro comprises a remote camera system and PC-based simulator. It uses active IR lighting so that it can provide high accuracy under all conditions, from bright sunlight to shadows. Also, it has the possibility to use with contact lenses, eyeglasses and sunglasses. It has the most flexible usage. Due to these useful features, it has been tested by automobile manufacturers to monitor the driver's eye and head tracking (Barr et al., 2005).

1.3. The Usage of Eye-Tracking in Psychology and Neuroscience

The eye has a sensitive working function connected to the central nervous system, and eye movements are considerably affected by disorders that occur the brainstem, the cerebral cortex, or the cerebellum. Damaged brain parts, dementia and several other brains related diseases can be understood by analysing the results of distorted eye movements (Vidal et al., 2012).

In some experimental psychology and clinical neuroscience researches, wearable types of eye tracking was used with between-eye movement and mental disorders. The analysis of eye movements was used to illustrate the reasonability of wearable eye tracking in the long-term recording of mobile setting for monitoring of mental health. Eye movements give different information that may contribute to mental health monitoring for conditions including autism, Alzheimer's disease, schizophrenia, dyslexia acquired immune deficiency syndrome dementia complex and multiple sclerosis (Lupu & Ungureanu, 2013).

2. The Evaluation of Eye- Tracking Methods

The identified eye-tracking methods are widely used in research, but they all have advantages and disadvantages in terms of usability evaluation. Head-mounted systems such as Eye Link II are compatible for tasks that require

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free head motion. For example, they can be used during walking, driving or some sports activities. Although these systems are able to considerably follow the eye movements linked to head movements, they are expensive and sensitive. Additionally, they partly hinder the observer gaze area, thus the observer is continually aware of the recording of eye movements. On the other hand, remote systems such as Tobii and Smart Eye Pro comprise a camera lens mounted on a computer display whereby participants can easily forget the existence of camera while performing immersive activities. These systems are cheaper than head mounted alternatives, but participants need to keep their head in a relatively stable position (Goldberg & Wichansky, 2003).

Data collection can be affected by pupil colour reflection using Eye Link 1000 and Eye Link II. If the pupil colour is too light incorrect data can be gathered. Furthermore, wearing eye-glasses or sunglasses can lead to some reflection problems obtained from the frames of glasses. Eye Link 1000 and Eye Link II are not suitable to use with glasses. Similarly, the ability to record eye movements is influenced by contact lenses and glasses using the Tobii eye tracker. Additionally, other factors such as make-up or eye-dryness have a negative impact on the results of eye-tracking studies due to possibility of getting distort outcomes. Consequently, not everyone can participate in eye-tracking studies (i.e. 10-20% of initially recruited participants, thus general outcomes cannot be obtained due to the representativeness of samples that intrinsically exclude people wearing glasses etc. (Schnipke & Todd, 2000; Jacob & Karn, 2003).

3. The Application of Eye- Tracking Methods in Memory Research

Human memory abilities show incredibly rapid development during the early years of life, associated with language acquisition. There are several changes connected to age with regard to infants' memory in terms of how they retain and recollect experiences of events (Hayne, 2004; Jones & Herbert, 2006). The exact time of memory retention can be affected by events that occur at the time of coding at any age, with extra encoding time being required for infants (Barr, Dowden, & Hayne, 1996), producing the relationship between the target events and recalled long-term events to extend retention time for target actions (Barr, Vieira, & Rovee-Collier, 2001, 2002). Similar to these, there is an opportunity to rapidly reproduce target actions (Herbert, 2003; Taylor & Herbert, 2013) and providing language clues both in coding and retrieving (Herbert & Hayne, 2000; Herbert, 2011), which can make retrieval easier in some situations, due to similarity to past experiences for infants (related to their coding experience).

Although researchers have a strong foundation concerning how infants are able to retain and express their memories, this has been greatly facilitated by the more sophisticated communicative abilities of older infants, while little is known about how younger infants and babies react to events that occur during the learning phase. For example, from 6 to 12 months, coding time is necessary for the memory to continue during a certain retention interval in half (Rose, 1983; Barr et al., 1996). Even though there are similar encoding abilities between younger and older infants, the former are able to do lower rate coding so that different encoding times related to ages have remained unclear. It can be proposed that the learning process of younger infants can affect this situation (Jones & Herbert, 2006).

In literature, there are some studies about infants learning process with using eye-tracking systems. Eye-tracking methodology was used as the most suitable system to investigate early learning processes and their association with memory due to include visual attention. Because infants are not able to give responses verbally or generate specific motor behaviour, they need to look at subjects or objects (Fagan, 1970; Gredebäck et al., 2010). Scanning images and events provide significant information about things perceived by infants that can potentially be used for encoding and later memory recall.

Preliminary research in this area concluded from eye tracking that, compared to older infants, younger infants' attention can be dispersed more easily and broadly when complicated events are observed; for instance, when a target and a distracter were shown on the screen randomly, three-month old babies were more focused on distracters than those aged 6-9 months (Amso & Johnson, 2008).

The changes in the scanning models along with the advancement of the technology can enable better comprehension and interpretation of events observed by infants. Gredebäck et al. (2009) explored gaze perception using videos including different movements and their related action goal. It was observed that babies aged 10 months' old (hereinafter '10-month babies') watched without the direction of gaze perception for the goal of action, whereas 14-month babies could estimate the next actions and then change gaze direction. This result supported that infants' understanding depended on change of both age-related and different gaze models. Also, these outcomes show that infants of different ages have different attention abilities across a situation, leading to investigation of whether different viewpoints lead to different learning process and memory findings.

Similarly, to explore infant learning about an event, Taylor and Herbert (2012) investigated how to attract the attention of the babies and whether there is a memory recall for event features, and whether age-related differences are manifest. To examine these relationships, a video was shown by means of puppet imitation task that including puppet, person, and background for 6- and 9-month babies, while the eye-tracking device recorded their visual attention. After the video was presented, babies' recognition memories were tested using Visual Paired Comparison (VPC) task by object, person and background familiarities. It was proposed that different visual components can lead to various attentions that affect the process of recognition memories for new situations, associated with age differences.

Consequently, Taylor and Herbert (2012) posited that more attention would be measured for a puppet, reflecting the most important cue for memory retrieval, compared to other stimuli, however the results indicated that although infants tended to watch central features in a target video, there was insufficient evidence to indicate recognition of single components of events, thus memory performance was not found to be affected by age in terms of changes in attention focus during memory coding. To sum up, eye-tracking methodology offers an opportunity to determine what aspects of an event are the focusing point of baby's visual attention in encoding of memory at the infancy research. To conclude, new eye-tracking technology was used to analyse that how babies will use the information observed at the time of encoding with well-structured memory processing later (Taylor & Herbert, 2012).

Liu et al. (2011) investigated whether infants' facial perceptions were related to race information and recognition memory, examining Asian infants' fixation duration by means of eye-tracking methodology for both same-race (Asian) and other-race (Caucasian) of female faces. The babies were aged 4-9 months. A visual stimuli task was designed using Tobii eye tracker. Firstly, a cartoon character was shown to attract infants' attention and then they were presented with own-race female face and other-race female face on the screen. The whole face and internal features such as eyes, noses were used to compare the face race differences. The results show that the same-race faces appeared clearly for 3-month babies, whereas to comprehend recognition memory differences, babies should be between 3-9 months' old. The eye-tracking procedure provides information about both similarities and differences in the processing of babies' own and other race faces (Liu et al., 2011).

Richmond and Nelson (2009) tested a new eye-tracking method to measure relational memory activities for 9-month babies using scene and face images as visual stimuli. The relationships between faces placed on different scenic backgrounds were learnt by babies. Three faces were shown together with the familiar scene. Although all three faces were similarly well-known, one had been given with the test background before. The behavioural results were recorded by means of Tobii eye tracker system. Infants tended to look at the faces presented as a test background earlier. These results proposed that 9-month babies can create memories that indicate relationships among items. Richmond and Nelson (2009) emphasized that the measurement of eye-movements is very significant in order to comprehend developmental relational memory. In contrast to other eye-tracking and memory studies, this task does not depend on motor skills in terms of the age-related changes. Therefore, eye movement paradigms reflect indeed developmental approach and have the ability to be used throughout the entire lifetime.

4. Conclusion

Recently, eye-tracking studies have become increasingly popular in numerous disciplines due to the convergence of the long-acknowledged import of the implications of eye movement and the novelty of effective methods by which to assay and analyse such movements since the 1970s onwards, and particularly over the last two decades due to technological developments. Although there are advantages and disadvantages of various eye trackers in common use, they all provide significant information about human cognitive process. Thus, eye-tracking systems are widely used in psychology-related fields.

This review discussed eye-tracking methods generally, specifically focused on memory and eye-tracking combined research, and evaluated different studies using eye-tracking method. In conclusion, the findings obtained using eye-tracking represent an important step for psychology researchers, however the presence of certain problems must be acknowledged, such as individual equipment differences and subject-related hindrances (e.g. wearing make-up or glasses) and the problem of the generalization of results.

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