Pupillary System & Task-Evoked Pupillary Responses

12627 S/E: Neurocognitive Psychology
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“It is said that the eye is a window to the soul, however, the pupil provides psychophysiology with a window to the brain“

Beatty, J. (1986). chapter three: the pupillary system, 43

1. the eye
1.1 anatomy of the eye

- a spherical structure
- 3 tissues: cornea, choroidea, retina

Illustration 1: anatomy of the eye
reference: Dr. Goldmann, D.R. (2002), Medizin & Gesundheit, 567

1.2 function of the eye

- transformation of pictures into electrical signals
- cerebral cortex: production of three-dimensional impression
- combination of information of other senses

Illustration 2: function of the eye
reference: Dr. Goldmann, D.R. (2002), Medizin & Gesundheit, 568
2. pupillary system

2.1 anatomy and physiology of pupillary system

- regulation of pupillary diameter by 2 groups of smooth muscles:
  - the dilator pupillae
  - the sphincter pupillae

reference: Dr. Goldmann, D.R. (2002), Medizin & Gesundheit, S. 568
2.2 functions of the pupil

- pupillary diameter -> environmental illumination
- changes of the pupillary diameter -> control of the depth of field of the eye
- reducing pupillary diameter -> aberrations of the eye's optical system

2.3 reflexes

- **the light - reflex:**
  principal determinant of pupillary diameter

- **the near - reflex:**
  - link with the activity of the ocular - motor system
  - constriction -> increasing the depth of the field of the visual system

- **the psychosensory reflex:**
  dilation -> mental processes
3. measuring of pupillary responses

3.1 photographic pupillometry

- the older, simpler and less expensive one

- beginning:
  - photographing the pupil of one eye
  - using a macro - focusing motion picture camera

- 16 mm - film or 35mm - film

- also infrared film

- the developed film -> projecting the image of the eye onto a large surface
  - measuring the pupil -> ordinary yardstick
3.2 electronic video - based pupillometry

- high-resolution linear infrared video camera
- series of hardware pattern recognition circuits -> extraction of boundary separating iris and pupil
- pupil area or vertical pupillary diameter -> computed electronically
- acquisition of pupillometric data, on-line artifact detection and response averaging

Reference

- Beatty, J. (1986), Chapter three: Pupillary System, 43 – 50
- Dr. Goldmann, D.R. (2002), Medizin & Gesundheit, Starnberg: Dorling Kindersley Verlag GmbH, 566 - 570
Task-Evokes Pupillary Responses and Processing Load
A Review of experimental data

Content
1. Introduction
2. Kahneman’s 3 criteria
   2.1 Within-Task Variations in Processing Load
   2.2 Between-Task Variations in Processing Load
   2.3 Between-Individual Variations in Processing Load
3. Conclusion

1. Task-Evoked pupillary response as a tool for measuring human cognitive processes - Possible?

- Pupillary dilations that accompany cognitive processes occur at short latencies following the onset of processing and subside quickly once processing is terminated
- The magnitude of pupillary dilation appears to be a function of processing load required to perform a cognitive task
- These facts led Kahneman (1973) to rely on the task-evoked pupillary response as the primary measure of processing load
2. Kahneman's 3 criteria for any physiological indicator of processing load

1. It should be sensitive to **within-task variations** in task demands, produced by changes in task parameters
2. It should reflect **between-task differences** in processing load elicited by qualitatively different cognitive operations
3. It should capture **between-individual differences** in processing load

2.1 Within-Task Variations in processing load, 1st criteria

- Task-Evoked pupillary responses have been obtained for a wide variety of cognitive processes like
  - sensory detection
  - memory
  - language processing
  - attention
  - complex reasoning
2.1.1 Within-Task Variations in processing load
Task-Evoked Pupillary Responses in Short-term memory tasks

- Kohneman and Beatty (1966):
  - Strings of 3 – 7 digits were aurally presented at the rate of 1 per second
  - After a 2-sec. pause, repeat the digit string at the same rate
- Pupillary diameter increases with presentation of each digit
- During report, pupillary diameter decreases with each digit spoken and reaching baseline levels after final digit

2.1.2 Within-Task Variations in processing load
Task-Evoked Pupillary Responses in Language processing tasks

- Study of processing meaningful sentences of different complexity (Ahern, 1978)
  - Presented Sentences: „A follows B“ or „B precedes A“
  - Following exemplar „AB“ or „BA“
- Task: was to determine whether the sentence correctly described the exemplar
- Peak during the decision interval
2.1.3 Within-Task Variations in processing load

Task-evoked pupillary responses in Mental Arithmetic Tasks as indicator for Reasoning

- Hess an Polt (1964) measured pupillary diameter as 5 subjects solved 4 multiplication problems, ranging in difficulty from 7x8 to 16x23
- for each of the problems the pupillary diameter increased from the moment of problem presentation until the point of solution
- percentage of dilation was perfectly ordered by difficulty of the problem

2.1.4 Within-Task Variations in processing load

Task-evoked pupillary responses in Perceptual Detection Tasks

- Uniform visual field on which brief increments in luminance could be imposed as pupillary diameter was measured
- clear pupillary dilation of approximately .10 mm was observed, if a presented target was detected
2.2 Between-Task Variations in Processing Load; the 2nd

Task-evoked pupillary responses as an index of between-subject variations of processing load imposed (Ahern, Beatty; 1979)

2 groups (low an high intelligence) of university undergraduates, differed in by SAT measured intelligence

4 tasks

- the more difficult tasks elicited larger pupillary responses
5. Conclusion

- Task-evoked pupillary response as a reliable measure method...
- In each of the experiments and checked criterias described, there appears to be an orderly relationship between the processing demands imposed by a cognitive task and the amplitude of the task-evoked pupillary response.
  - The proof, at least for Beatty, is given

6. Reference