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Too resilient for anyone's good: "Infant psychophysics" viewed through second-order cybernetics, Part 1 (background and problems)

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Too resilient for anyone's good

"Infant psychophysics" viewed through second-order cybernetics, Part 1 (background and problems)

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Abstract

Purpose – This study aims to examine the observer's role in "infant psychophysics". Infant psychophysics was developed because the diagnosis of perceptual deficits should be done as early in a patient's life as possible, to provide efficacious treatment and thereby reduce potential long-term costs. Infants, however, cannot report their perceptions. Hence, the intensity of a stimulus at which the infant can detect it, the "threshold", must be inferred from the infant's behavior, as judged by observers (watchers). But whose abilities are actually being inferred? The answer affects all behavior-based conclusions about infants' perceptions, including the well-proselytized notion that auditory stimulus-detection thresholds improve rapidly during infancy.

Design/methodology/approach – In total, 55 years of infant psychophysics is scrutinized, starting with seminal studies in infant vision, followed by the studies that they inspired in infant hearing.

Findings – The inferred stimulus-detection thresholds are those of the infant-plus-watcher and, more broadly, the entire laboratory. The thresholds are therefore tenuous, because infants' actions may differ with stimulus intensity; expressiveness may differ between infants; different watchers may judge infants differently; etc. Particularly, the watcher's ability to "read" the infant may improve with the infant's age, confounding any interpretation of perceptual maturation. Further, the infant's gaze duration, an assumed cue to stimulus detection, may lengthen or shorten nonlinearly with infant age.

Research limitations/implications – Infant psychophysics investigators have neglected the role of the observer, resulting in an accumulation of data that requires substantial re-interpretation. Altogether, infant psychophysics has proven far too resilient for its own good.

Originality/value – Infant psychophysics is examined for the first time through second-order cybernetics. The approach reveals serious unresolved issues.

Keywords Second-order cybernetics, Perception, Threshold, Observer, Infant, Psychophysics

Paper type Research paper

1. Introduction

"Resilience" may be loosely defined as adaptability to change or adversity. Resilience allows ideas and entities to evolve. However, as Elmqvist *et al.* (2017, p. 352) note, "Resilience may not always be desirable – witness dictatorships that are resilient across generations." In other words, political evolution can benefit some but not others. As in politics, so too in science, which the taxpayers support. A research paradigm may prove to be too resilient; that is, a particular idea and its associated methods may persist beyond the limits of usefulness. For example, a mainstay of cybernetics, namely, Information Theory has been

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used unjustifiably for more than a half century in perceptual psychology and in neuroscience (Nizami 2010, 2011a, 2011b, 2012, 2013, 2014, 2015; Susswein, 2013; after Shannon, 1956, Wiener, 1956, and Johnson, 1970).

The present work exposes a case of excessive resilience, called "infant psychophysics." Infant psychophysics has cost millions of dollars and occupied thousands of man-hours world-wide over the past 55 years. It is critically reviewed here, and under constant mindfulness of a second-order cybernetics concern, *the role of the observer*. Serious problems emerge.

Scrutiny of infant psychophysics is certainly timely. In the March 2016 issue of *American Scientist*, the journal of the 290,000 members of Sigma Xi (The Scientific Research Society), experimental psychologist R.D. Hamer celebrates the resilience of an infant-psychophysics method called *forced-choice preferential looking* (explained below). It was proselytized by Professor Davida Teller, a former co-author of Hamer (Hamer *et al.*, 1982; Schneck *et al.*, 1984). The method was intended to assess infants' perceptual abilities. Now, infants are notoriously difficult subjects for psychology experiments, such as stimulus-detection or stimulus-discrimination. Those tasks require that a decision be made about a stimulus, such as "it is barely visible" or "it is louder than another sound." For adults, such a decision rapidly follows an instant of introspection, the decision being reported verbally or (for example) by pushing a button. Such self-report, however, is impossible for infants. Hence, some behaviors displayed by infants are quantified, to infer infants' capabilities. The relevant methods are reviewed here, followed by criticisms from a second-order-cybernetics perspective. Further methods, criticisms and conclusions follow in a second paper (Nizami, 2018).

A version of Teller's method, but tailored to test infants' *hearing*, was introduced by Olsho *et al.* (1987). Hundreds of similar papers subsequently accumulated. The study of infant perception is now a world-wide, multi-laboratory, multi-million-dollar endeavor. It continues to broaden in scope. By 2012, enough infant-hearing studies had been published to justify a book, *Human Auditory Development* (see Werner, 2012). A salient finding of that book is a rapid decrease of auditory detection thresholds during infancy, i.e. infants' hearing improves with time. Further, a two-page spotlight on the Werner laboratory (Lau and Ng, 2017) and a longer feature on cochlear auditory implants (Svirsky, 2017) appeared in recent issues of *Physics Today*, the magazine of the American Institute of Physics ("approximately 120,000" members; https://www.aip.org). Indeed, implants are a recommended treatment for infants deemed to be profoundly hearing-impaired (Svirsky, 2017).

The study of infants' detection/discrimination ability in vision and in hearing is ongoing. Therefore, it is discussed here using the present tense. Additionally, quotations are used, to convey the original flavor of the literature, as well as to avoid any appearance of misrepresentation. Units-wise, this paper uses dB SPL, which means "decibels sound-pressure-level" (Hartmann, 1998), the standard for research measurement of objective auditory waveform pressure.

2. "Preferential looking": the beginning of modern infant psychophysics

2.1 Fantz and colleagues test infants' visual acuity

Modern infant psychophysics started not with the hearing system but with the visual system. From the late 1950s through the 1960s, Fantz and colleagues tested the visual acuity of infants. Let Fantz *et al.* (1962, p. 907) themselves explain (italics supplied):

> If we present a graded series of patterns and find the smallest which elicits a *differential ocular response*, we know that visual detail at least that fine can be resolved.

Note well the profound assumption that *a "differential response", whatever that is judged to be, indicates differential perception*. This assumption underlies all subsequent work on infant psychophysics. Nonetheless, it remains unsubstantiated. Indeed, a "differential response" may indicate any number of things, including mere *distraction*. This possibility is addressed at length in the companion paper (Nizami, 2018).

The method used by Fantz and colleagues remained the same throughout their work. Indeed, some particular details set the stage for all further infant psychophysics:

> The procedure was to place an infant in a crib inside a test chamber and to expose above him a striped pattern and a plain gray comparison object for 20 sec (Fantz *et al.*, 1962, p. 908).

In particular:

> The lower half of the front side of the chamber was open so that a small hammock-type crib could be rolled underneath until the infant's head was directly under an observation hole in the center of the ceiling (Fantz *et al.*, p. 908).

Further, "The stimulus objects were attached to the ceiling to the right and left of this ¼-in. peephole [i.e. the observation hole]" (Fantz *et al.*, p. 908). Those stimulus objects were "squares with vertical black and white stripes of equal width … each presented with [i.e. opposite from] the same gray [comparison] square, matched in luminous reflectance" (Fantz *et al.*, p. 908). Additionally:

> "The inside of the chamber was a nonglossy, dark saturated blue color which tended to quiet the infants and gave a contrasting background for the lighter achromatic objects", i.e. for the grey and striped "stimulus objects" (Fantz *et al.*, p. 908).

The experimenters observed the infant through the chamber's ceiling peephole, noting that:

> Tiny reflections of the stimulus objects were clearly visible on the [infant's] cornea […] The location of one of these reflections over the pupil provided a simple criterion of fixation (Fantz *et al.*, p. 908).

That is, "If the left reflection was over the pupil, for example, the infant was looking at the object on the left" (Fantz *et al.*, p. 908).

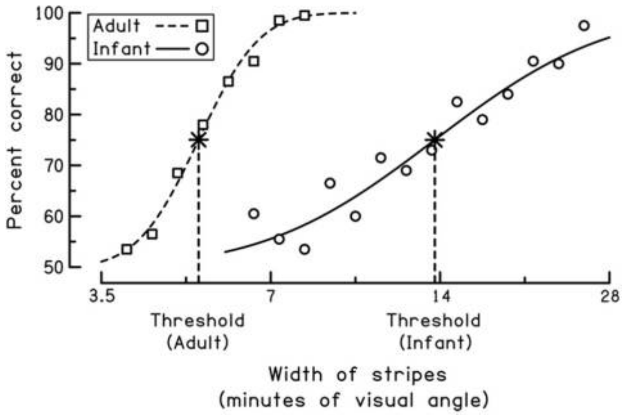
The observer determined *how long* and *how often* each of the two alternatives (the striped pattern and the plain gray comparison) was fixated during each single 20-s presentation interval. The infant (and the observer) had no obligation to choose only one stimulus instead of the other. Rather, Fantz *et al.* assumed that an infant could discriminate the striped "object" from the plain gray comparison square if the infant fixated the former for longer than the latter, in at least 75 per cent of the 20-s viewing sessions for the particular stimuli. The thickness of the respective stripes was then the "threshold" thickness, with yet-thicker stripes being presumably progressively easier to discriminate from gray. The infants were 1-22 weeks old. Later, Fantz (1963) tested subjects from 10 hours old to 5 days old, apparently using the same set-up.

In Fantz (1963, 1965), only the first fixation time for the striped object was recorded; its discrimination from the gray object was still determined by whichever was fixated for a longer time.

2.2 Fantz's conclusions, including an underemphasized data-phenomenon that recurs

Over the years, Fantz concluded that infants can discriminate from birth between stripes and unpatterned surfaces, and that over the course of the first six months of age, infants can discriminate narrower and narrower stripes. However, Fantz also illustrates a result which appears (and gains importance) on later studies of infant visual and auditory detection/discrimination thresholds. That is, Fantz *et al.* (1962, pp. 910, 915) plot the number of *trials* (i.e. choices) on which the infant fixates the stripes for longer than the plain gray stimulus, as a percentage of the total number of trials with those particular stripes, yielding a set of data points, one for each width of stripes. Wider stripes empirically correspond to higher percentages. The data-plots tend to be crudely S-shaped, and that data-plot or any smooth curve fitted to it is called a *psychometric function* (Green and Swets, 1966/1988; Macmillan and Creelman, 1991). The midpoint of the psychometric function is traditionally taken as indicating the detection/discrimination "threshold" (Green and Swets, 1966/1988; Macmillan and Creelman, 1991). The psychometric function ideally has an upper asymptote which approaches 100 per cent and a lower asymptote which approaches the *average* chance performance, which is 50 per cent in two-interval forced-choice tasks (Green and Swets, 1966/1988; Macmillan and Creelman, 1991), although scores as low as zero are theoretically possible.

Fantz *et al.*'s psychometric functions are interesting, because their slopes prove remarkably shallow relative to what might be expected from adults performing similar discriminations. Figure 1 shows a schematized example of this difference for a Fantz-type experiment. Shallow slopes for infants suggest that a distinct "threshold" is illusory. This is important, because shallow slopes appear in later vision and hearing stimulus-detection studies with infants (Nizami, 2018).



Notes: The squares or circles are examples of actual percentages-correct achieved by the research subject. Here, they are regression-fitted by a smooth curve which is a cumulative Gaussian function. The centroid of that curve (here, the asterisk) indicates the corresponding stripe width, which is taken as the stimulus-detection threshold (at the dashed vertical line).The scales are based on Fantz *et al*. (1962, Figure 4). Because there are two alternative visual stimuli (stripes or plain gray), the average chance performance is 50 per cent (Green and Swets, 1966/1988; Macmillan and Creelman, 1991)

Figure 1. Examples of psychometric functions for adults and for infants in a vision experiment to differentiate stripes from plain gray (Section 2)

3. Preferential looking applied to infant-hearing thresholds

3.1 Hoversten and Moncur (1969)

Soon, preferential looking was adapted for infant-hearing studies. The details are crucial, as follows. Hoversten and Moncur (1969) tested three-month-old and eight-month-old infants using five stimuli: "white" noise (a hissing sound, having equal energy at all waveform frequencies within a broad band), 0.5-kHz tones, 4-kHz tones, a woman's voice, and a short passage of notes from a children's song. The tones and the white noise were each presented as six pulses (*all* stimuli, therefore, displayed "amplitude modulation," perhaps to attract the infant's attention.) Each stimulus was presented to a loudspeaker on the left or on the right (chosen at random) of the infant. Two observers were used, one sitting to the right front of the infant, the other to the left. The observers independently marked charts of 20 possible changes in the infant's behavior. In other words, the judges were restricted to pre-ordained possibilities. Those possibilities included "widening or moving the eyes," "a decrease or cessation of activity," "looking at the observer" and "localization."

The observer-given grades were only registered when the two observers were in agreement. The percentage of correct responses, thus judged, rose with the intensity of each stimulus. The woman's-voice stimulus produced the highest percentage-correct scores at any stimulus intensity. For three-month-olds, the *overall* stimulus-detection threshold, averaged over *all* stimuli, was 43 dB HL, where HL ("hearing level") means "relative to the detection threshold for young adults" (which was established separately). Thus, three-month-olds had hearing that was 43 dB less sharp than that of young adults.

The greater effectiveness of the woman's voice suggests that distraction, rather than mere detection, determined the infants' thresholds. This hypothesis is pursued in the companion paper (Nizami, 2018).

3.2 Thompson and Thompson (1972)

Like Hoversten and Moncur (1969), Thompson and Thompson (1972) made important contributions to the early methods. Like Hoversten and Moncur (1969), Thompson and Thompson (1972) used two observers for each infant. But those watchers are now separated: "One examiner was located in the test room with the child. The other observed the child's behavior from the control room" (Thompson and Thompson, p. 702). The Thompson and Thompson (1972) subjects were 7-36 months old. The stimulus, which was 2 s long, could be a brief speech phrase, a white-noise burst, or one of those same stimuli with components below 2 kHz filtered-out, or a 3-kHz tone.

During the experiment, "The child was placed on his or her mother's lap in the test room" (Thompson and Thompson, p. 702). Further, "Soft colorful toys were available to occupy the child during the test, which took approximately 30 minutes" (p. 702). Further still, "The mother was instructed not to respond in any way to test stimuli and to be completely quiet during the test session." During that session, "Stimuli were presented on a random basis", through one loudspeaker or the other. Of course, the latter procedure allows the mothers, too, to hear the stimuli, perhaps producing subtle changes in "body language" that might indicate the stimulus to the infant. This potential cue was later avoided in other laboratories, by obliging the mothers or other infant-handlers to wear headphones that supplied irrelevant noise or music, masking the presence of the actual stimuli (see below).

Regarding the Thompson and Thompson (1972) "response criteria", they state that "Response criteria included localization and awareness to sound. Localization was defined as a head turn in the direction of the sound source" (p. 702), where the sound source was either of two loudspeakers. (Head turns were later ruled insufficient for infants younger than 5 months of age; Olsho *et al.*, 1987.) Regarding awareness, "Awareness was defined as either a movement of the eyes in the direction of the sound source, or looking up, usually at the examiner or the mother" (p. 702). The latter criterion seems particularly loose; how does glancing at any person in the room definitively indicate detection of a test stimulus, unless that person is actually holding the stimulus source (here, the loudspeaker)? Unfortunately, such loose criteria have propagated through the literature, as will be shown.

4. Teller and colleagues: forced-choice enters preferential looking

4.1 Differences from Fantz's methods

Teller *et al.* (1974) and Teller (1979) were aware of the "preferential looking" method of Fantz *et al.* (1962). In fact, they partly adopted the Fantz *et al.* (1962) methods. Teller (1979) provides the best explanation of their laboratory's techniques, as follows. They present a grating (striped pattern) on one side (left or right) of a center-point. Here, however, they diverge from Fantz *et al.* (1962) by having nothing but a luminance-matched gray background as the other "stimulus object," rather than having a distinct gray object on a common, darker background (Fantz *et al.*, 1962). To explain: "The infant is shown a homogeneous visual display, in which a single visual stimulus is embedded, in a variable position" (Teller, 1979, p. 143).

Teller and colleagues diverge yet again from Fantz *et al.* (1962), in that the infant is now upright and is in contact with a human being, rather than lying horizontally alone in a crib. That is:

> The [infant-] holder holds the infant in front of the display screen [. . .] In most cases the infant is held in a roughly vertical position, or leaning slightly forward, facing away from the holder (Teller, 1979, p. 140).

Further:

> Between [data-gathering] trials, the holder typically steps backward or rotates away from the visual display, and directs the infant's attention toward other interesting visual stimuli in the room (pictures, objects, or people) (Teller, p. 142).

Actual data-gathering proceeds as follows. The person called the "observer", who is the adult infant-watcher, is "located behind a peephole at the center of the [stimulus-projection] screen" (Teller, 1979, p. 136). The observer has help from the infant-holder:

> At a signal ("go") from the experimenter, the holder moves forward and/or rotates slowly toward the screen, in order to point the infant's head and eyes first toward the peephole, then toward one of the potential stimulus positions, then toward the other, back toward the central peephole, and so on until the observer has enough information to be willing to *guess* the stimulus location (Teller, p. 142; italics supplied; original internal quotation marks).

In short, at least two intervals of time are required (the turning of the infant), after which the observer must decide between the two possible locations of the grating (left or right), making the experimental task altogether a 2- (or more) interval 2-alternative forced-choice task. Such a task is well-known in psychophysics (Green and Swets, 1966/1988; Macmillan and Creelman, 1991).

Note again that the infant-holder herself is not the observer; in fact, the infant-holder is prevented from seeing the actual stimuli, by a baffle or an eye-shield, and thereby prevented from cueing the infant. Nonetheless, "Frequent small changes are made in the infant's position. The infant often sucks on a pacifier during testing" (Teller, p. 140). Further:

> The holder keeps the infant in almost constant motion back and forth in front of the display, to optimize the likelihood that the infant's eyes will catch and fixate the stimulus. Rocking, singing,

> interesting noises, etc., are used by the holder to maintain the infant's alertness and good humor (Teller, p. 141).

Given all of these conditions, "A trial can last from perhaps 2 sec (for highly salient stimulus conditions) to perhaps 1 min (for difficult stimulus conditions)" (Teller, p. 142).

4.2 Watchers forced to make choices

The actual infant-watcher's role is best expressed by Teller (1979, p. 141):

> During each trial the observer is naïve concerning the stimulus conditions and the position of the stimulus. The observer's task is to use information supplied by the infant, to infer the position [left or right] of the stimulus on each trial.

The observer is then told whether their inference is correct or incorrect (i.e. feedback). This differs from the auditory studies of Hoversten and Moncur (1969) and Thompson and Thompson (1972). Also, Teller diverges from the vision studies of Fantz *et al.* (1962). First, the infant-watcher allegedly never uses corneal reflections to make judgments (Teller *et al.*, 1974, p. 1434). Rather:

> The observer's criteria for judging the position of the stimulus vary from infant to infant and from trial to trial. In general, the direction of first fixation, steady fixation on one stimulus position, and, for a moving infant, compensatory eye and head movements to maintain fixation on one stimulus position, are the strongest and most reliable cues (Teller, 1979, p. 141).

There are others:

> Individual infants give other cues (eye widening, or alternation of fixation followed by steady fixation of one side, for example), and some give more false cues than others, requiring more caution on the part of the observer. The trial-by-trial feedback provided by the experimenter allows observers to adapt readily to these individual differences between infants (Teller, p. 141).

4.3 Construction of psychometric functions

Recall that the experimenters present the infant with a grating (striped pattern) on one side (left or right) of a center point. Based upon the infant's behavior, the watcher declares which side contains the grating. As such, the watcher is either correct or incorrect, and is scored as such by a laboratory analyst (a student, postdoc, professor or other staffer). The analyst can then plot percentages-correct versus the width of the stripes in the grating, yielding a set of data-points. Such plots (Teller, 1979) look like psychometric functions (see above), because wider stripes generally corresponded to higher percentages-correct. However, no individual infant provides enough data to build a psychometric function. Hence, the functions are built by averaging percentage-correct scores over many infants of similar age. This was also done by Fantz *et al.* (1962) and Thompson and Thompson (1972) and would be done in later hearing research (see below). Empirical psychometric functions for infants are remarkably shallow in slope as compared to what is found for adults, even allowing for the use of *logarithmic* x-axis scales by Fantz *et al.* (1962) and Teller (1979). This finding of shallow slopes proves crucial to the interpretation of infants' auditory stimulus-detection thresholds, and is reserved for the companion paper (Nizami, 2018).

5. Werner and colleagues: forced-choice preferential looking enters auditory studies

5.1 Olsho et al. (1987)) adopt the method of Teller (with notable changes)

Lynne Werner Olsho (later Lynne A. Werner) and colleagues obtained hearing "thresholds" from children less than six months old, starting with Olsho *et al.* (1987). The latter paper continues to be cited as the pioneering work in infant *auditory* psychophysics (He *et al.*, 2007; Smith and Trainor, 2011; Bonino and Leibold, 2017).

Olsho *et al.* (1987) start from Teller's (1979) work on two-interval forced-choice looking. They make two crucial assumptions, in the form of declarations. First:

> If the observer [i.e., the watcher] can reliably judge the location of the stimulus in such a paradigm, then the infant must be providing a reliable behavioral cue to indicate discrimination of the two stimuli [that are presented on a two-choice task] (Olsho *et al.*, 1987, p. 628).

Here, "discrimination of" means "differentiation between". Olsho *et al.* further state (same page) that:

> The response is completely objective: On every trial [i.e. every forced-choice] the observer is either right or wrong about where the specified stimulus was located [i.e. to the left or the right].

But Olsho *et al.* (1987) now depart from Teller's (1979) two-interval scheme. That is, Olsho *et al.* (1987) instead use a *one-interval* scheme, a concept already well-known and well-used for detection thresholds in adult subjects (Green and Swets, 1966/1988). As Olsho *et al.* (1987, p. 628) explain:

> The observer watches the infant and must decide whether a specified sound, the *signal*, was presented to the infant on that trial. At the conclusion of the trial, the observer is given feedback, that is, informed whether a signal was actually presented (original italics).

Note well the resemblances to earlier methods, including the use of feedback to the watcher.

5.2 Further differences from earlier studies

The infant's physical experience resembles that in earlier studies, to some extent:

> The infant sits on the parent's lap while listening to sounds presented monaurally over lightweight earphones. The infant's attention is maintained at midline by an assistant [who is] manipulating toys (Olsho *et al.*, 1987, p. 628).

Furthermore (Olsho *et al.*, p. 629):

> At certain times a signal [i.e. an auditory stimulus] is presented. If the infant responds in such a way that the observer correctly decides that a signal has occurred, a mechanical toy [which is usually hidden from the infant] is activated to reinforce whatever response was made by the infant.

Reinforcement (of this kind and others) provides encouragement and therefore has been used for decades in other kinds of psychology experiments. Olsho *et al.* (p. 630) continue: "Obviously, both the parent and the toy waver [the assistant mentioned above] have to be kept "deaf" to the presentation of sounds to the infant" (original internal quotation marks). Furthermore, the parent, the infant, and the toy waver (but not necessarily the infant-watcher) are *all* within a soundproof chamber, greatly reducing environmental noise.

Olsho *et al.* (p. 629) further explain that "The reinforcer provides feedback [to the infant] for positive responses [i.e. changes in infant demeanor] detected by the observer." In other words, the *mechanical toy* is activated when the watcher indicates, based on the infant's behavior, that the stimulus has occurred when it *has*, indeed, occurred. Further (Olsho *et al.*, p. 629), "No feedback for negative responses [i.e. no recognizable change in infant demeanor] or undetected positive responses is available to the infant during testing." Infants only experience reinforcement when the stimulus is presented *and* the watcher correctly says so.

In agreement with Teller's (1979) practice of hiding the observer, and in a further break from earlier *auditory* studies such as those of Hoversten and Moncur (1969) and Thompson and Thompson (1972), the infant-watchers were situated strictly *outside* of the testing chamber:

> The observer sits in the adjacent control room, watches the infant through the window [of the chamber] or on a video monitor (or both), and makes judgments on a trial-by-trial basis (Olsho *et al.*, 1987, p. 630).

The judgments were based on "eye movements," "eye widening and other changes in facial expression," "head turns", and "changes in activity level" (Olsho *et al.*, p. 631). However, Olsho *et al.* also note that "It is often the case, of course, that the observer cannot define the response(s) that are the basis for judgments" (p. 631). In other words, a data-gatherer's *intuition* lies behind data appearing in peer-reviewed scientific journals! The watcher in Trehub *et al.* (1991), for example, "could use any available cues to support their judgments" (Trehub *et al.*, 1991, p. 42). Elsewhere, for example in Tharpe and Ashmead (2001, p. 105), the watcher "was actually free to focus on any aspect of the infant's behavior." All of this echoes Teller's (1979, p. 138) statement that their watcher used "any available information supplied by the infant."

The toy-waver also seems key to the Olsho *et al.* (1987) experiment, not least for preventing the infant from losing attention (Olsho *et al.*, p. 630). Regardless, it was the shape of the plot relating the infant-watcher pair's score, in percentages-correct, to the intensity of the stimulus – namely, the psychometric function – that Olsho *et al.* (p. 634) called "The major criterion used to determine whether the method was satisfactory for younger infants." Olsho *et al.* (1987, p. 635) declared that those psychometric functions were "reasonable." Later, Werner and Gillenwater (1990) would obtain psychometric functions for infants as young as two-five *weeks* old.

5.3 The Olsho et al. (1987) method is ongoing

The Olsho *et al.* (1987) method continues to be used for infants six months of age and older (Werner and Boike, 2001; Leibold and Werner, 2006; Grieco-Calub *et al.*, 2008; Dasika *et al.*, 2009; Werner *et al.*, 2009; Grieco-Calub and Litovsky, 2012; Hüg *et al.*, 2014; Leibold *et al.*, 2016), and may still be used for younger infants too. Younger infants are, in fact, being tested using *non-behavioral* physiological methods; those methods have their own problems and are described in the companion paper (Nizami, 2018). Given the ongoing use of the Olsho *et al.* (1987) psychophysical method, closer scrutiny of it seems well-justified. As the particulars derive directly from Teller's methods (Teller *et al.*, 1974; Teller, 1979), we must perforce begin with Teller.

6. Problems with Teller's preferential-looking method

In discussing her research subjects' psychophysical task, Teller (1979, p. 143) stated that "The forced-choice preferential looking technique as discussed up to this point provides the infant with a psychophysical detection task." But she is wrong. It is the watcher-infant duo who perform the task, not merely the infant. Teller (1979, p. 138) seems to initially recognize this:

> The observer is a *subject* in the sense that he or she is faced with a forced-choice task, namely, to judge the position of the stimulus on each trial, using any available information supplied by the infant (italics supplied).

Then, remarkably, in the rest of her paper Teller seems to forget that "the observer is a subject."

When the data are later interpreted by a laboratory analyst, it is the entire laboratory that effectively becomes the observer. Figure 2 shows who constitutes the "observer," which changes with successive interpretations from the viewpoint of second-order cybernetics.

The 1-interval 2-alternative (Yes/No) auditory task used subsequently by Olsho *et al.* (1987) and her successors maintains this ambiguity, namely, that the detection performance is that of a watcher-infant duo, not merely the infant.

7. Problems with the preferential-looking method of Werner and colleagues

7.1 The watcher-infant team: who, exactly, is being conditioned during operant conditioning?

Olsho *et al.* (1987) largely adopted their method from Teller (1979). Hence, any problems with Teller (1979) are likely to carry over to Olsho *et al.* (1987), and they do, as follows.

Recall from Section 5.2 Olsho *et al.*'s (1987, p. 629) description of the psychological reinforcement:

> At certain times a signal is presented. If the infant responds in such a way that the observer correctly decides that a signal has occurred, a mechanical toy is activated to reinforce whatever response was made by the infant.

Note well that this encouragement of the infant occurs only when the *watcher* is correct. The infant is not encouraged on the inevitable occasions when it reacts to the stimulus presentation but the watcher nonetheless *fails* to recognize the reaction. Further, the infant *is* encouraged if the watcher correctly *guesses* that the stimulus was presented, even if the infant did not actually hear it. Altogether, the infant is not being conditioned to respond to the stimuli; from the infant's point-of-view, sometimes a mechanical toy is revealed, and sometimes it is not. In contrast, the watcher is always told whether the stimulus was presented. But remember that the watcher cannot actually hear the stimulus. Hence, the watcher is continually being trained to "read" the infant.

There was a later change to the Werner protocol:

> At the beginning of each session, the level of the stimulus was fixed at 85 dB SPL and the mechanical toy was activated at the conclusion of each signal trial regardless of the observer's judgment (Werner and Marean, 1991, p. 1868).

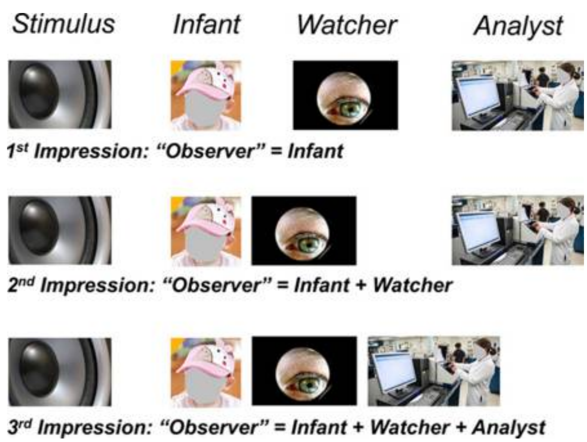


Figure 2. Successive impressions, from the viewpoint of second-order cybernetics, of who constitutes the "observer" (here effectively a *listener*) in infant psychophysics

That is, a loud auditory stimulus was paired with the activation of the toy. This was presumably done to link stimulus presence with toy activation, in the infant's mind, and later work involved similar conditioning (Werner and Bargones, 1991; Werner *et al.*, 1992; Werner *et al.*, 1993; Bargones *et al.*, 1995; Werner, 1999; Werner *et al.*, 2001; Leibold and Werner, 2006; Werner *et al.*, 2009).

Likewise, Schneider *et al.* (1989), Schneider *et al.* (1990) and Trehub *et al.* (1995) used a training condition. Oddly, Trehub *et al.* (1991) did not. Their rationale is that such training sessions render the overall procedure too time-consuming for practical diagnosis of hearing problems and furthermore that "It remains to be determined whether such training achieves its goal of enhancing the *observer's* performance or bringing it to some asymptotic level" (Trehub *et al.*, p. 42; italics supplied). This issue is still unresolved.

7.2 The watcher-infant team: how "readable" are infants?

Olsho *et al.* (1987) seem to recognize a problem with the use of what they call "the observer-infant team" (p. 638). That is:

> If we are investigating pure-tone sensitivity and fail to surpass chance performance [of the observer-infant team] at low sound pressure levels [SPLs of the stimulus], then it would not be unreasonable to suggest that the infant's response to very quiet sounds is so subtle that the observer is unable to detect it (Olsho *et al.*, p. 638).

If so, then, "The observer's threshold for detecting an infant response is higher than the infant's threshold for detecting a sound, and the infant's capacity would be underestimated" (p. 638). But by how much? The answer is crucial to the whole approach of inferring thresholds from visual observations. As Trehub *et al.* (1991, p. 45) note, "Infants varied considerably in their expressiveness or propensity to exhibit overt reactions to sound." Hence:

> Individual differences in expressiveness are necessarily problematic for any observational measure of auditory sensitivity, so that underestimates of sensitivity are likely to result from relatively inscrutable infants with intact hearing (Trehub *et al.*, p. 45).

Trehub *et al.* (1991) evidently recognize what Olsho *et al.* (1987) recognize, namely, that infants' thresholds are likely to be lower (i.e. better) than experimenters infer. This issue underlies much of the critique in Nizami (2018).

Further complications abound. Cues from the infant "may not be identical for high- and low-intensity signals" (Trehub *et al.*, 1991, p. 42). Indeed, as Trehub *et al.* (p. 42) explain, "Attenuation of limb movement may be the characteristic response to signals of high or moderate intensity, whereas subtle eye widening or eyebrow movement may be relevant for low-intensity signals".

7.3 The watcher-infant team: disagreements across watchers

It was mentioned earlier that Hoversten and Moncur (1969) and Thompson and Thompson (1972), unlike the Werner lab or the Schneider/Trehub lab, actually employed *two* observers to watch and judge each infant. Hoversten and Moncur (1969) note that their judges agreed 80 per cent of the time when watching three-month-olds and 89 per cent of the time when watching eight-month-olds. Given this evident difference with infant age, does an infant's response to sensory stimuli become easier to read – with greater agreement among watchers – as infants mature? This issue is returned to, below.

For any given infant age, the lack of total agreement between two judges suggests that watchers may differ significantly in their observational criteria for what constitutes detection of the stimulus by the infant. Moncur (1968, p. 348) thinks this to be non-trivial: "In single judge evaluations, the excessive exclusion of data is solved [thanks to having no second judge to disagree with], but the problem of correct judgment is magnified." Moncur investigated by exposing infants greater than seven months old to pulsed 0.5-kHz tones, a female voice, or music. Left and right loudspeakers were at 45 degrees in front of the infant's head. The infant was videotaped, and the tapes were shown to *panels* of judges after-the-fact. Two judging methods were used. In one method, ratings were assigned to an infant's "localization," "body movements," "facial movements", and "cessation or diminution" of activity, or "status quo" (i.e. no change in behavior). In another method, judges responded "yes" or "no" as to whether the infant apparently heard the stimulus, along with making a self-confidence rating of their judgment. The judges were either pediatric audiologists, or other audiologists, or "laymen." Moncur (1968) found that the pediatric audiologists had higher "test-retest agreement" (88 per cent) than laymen (82 per cent) and non-pediatric audiologists (79 per cent). Both of the judging methods (descriptions, or yes/no) yielded "approximately the same results" (Moncur, p. 355). In short, judges may indeed agree only 80 per cent of the time, and pediatric audiologists may be better judges than other university personnel.

Unfortunately, no-one seems to have acted on Moncur's (1968) conclusions. His finding of less-than-perfect interjudge agreement is also found in studies of infant vision. For example, pairs of judges watching infants exposed to Teller-style striped patterns agree as little as 67 per cent of the time (Mash *et al.*, 1995, and papers reviewed therein).

Olsho *et al.* (1987, p. 631) *trained* seven observers, but only employed them one-at-a-time. Indeed, Trehub *et al.* (1991) used only a single person to make *all* observations. She was identified elsewhere as Marilyn Barras, for "assistance in data collection" (Trehub *et al.*, 1988; Schneider *et al.*, 1990), suggesting that all of the data from the Schneider/Trehub lab over the course of several years actually represent the observational criteria (and personal biases) of one individual! Regardless, there is no mention of any of the observers being pediatric audiologists, or any other audiologists. At least, the watchers were not the experimenters. However, even this rule could be broken: in Tharpe and Ashmead (2001), for example, the person initiating the experimental trials was also the watcher.

Arora and Lutfi (2008) offer a model of the watcher's performance, based upon Signal Detection Theory. The model is too elaborate to be described here, but Arora and Lutfi particularly sought:

> [. . .] sufficient conditions on the statistical characterization of the judges to attain optimal detection performance. At the same time we develop expressions for the rate at which the estimation error decays with number of judges. This will give us the trade-off between the cost and accuracy of using multiple judges (Arora and Lutfi, p. 1851).

Arora and Lutfi suggest the advantage of using at least five or, better, seven simultaneous watchers. A hypothetical requirement that several watchers be present, and that *all* agree (for example) before the infant is considered to have "responded" to the stimulus, indeed constitutes a stricter stimulus-detection *criterion*, and the infant's inferred threshold would typically be higher. But as Nizami (2018) explains, higher thresholds may, in fact, be *less* credible. In any case, the Arora and Lutfi (2008) calculations do not retroactively make the infant-testing method itself any more credible.

7.4 The watcher-infant team: improvement in watcher agreement with infant age

Infants' stimulus-detection thresholds are inferred from what the infant attends to. Therefore, if there is any change over time in the *watcher's* ability to "read" the infant, it confounds with any change over time in the infant itself, such as an increase or decrease of the actual detection-thresholds. Now, the watcher's judgments are based at least partially upon reading the infant's *face*. Does that particular "watcher skill" change as the infant gets older? The answer seems crucial, and yet the present author found only a single study devoted to answering it. That particular study's authors were not even concerned with stimulus-detection thresholds *per se*.

Briefly, Galati and Lavelli (1997) videotaped three boys and three girls at three days, one month, and three months of age (always the same infants). Each time, the infants experienced the same five naturalistic situations that are traditionally believed to elicit different emotions. These situations were:

- immediately before feeding;
- forced movement (hip rotation during the medical examination [in the birth hospital]);
- in his/her mother's arms immediately after feeding;
- detaching from his/her mother (when the baby was put in the cot after feeding); and
- inoculation (for a blood test or vaccination) (Galati and Lavelli, p. 61).

The infants' faces were isolated post hoc in the videotapes. Furthermore, only those video segments were used which were approved as "truly connected to the eliciting situation" (p. 62) by a panel of five researchers "who were experts in coding the facial expressions of babies" (p. 62). Subsequently, non-expert groups of 30 undergraduate "decoders," one group for each of the three infant ages, viewed each videotape. The undergraduate decoders rated each infant's expressions according to its level of excitement and its level of displeasure, using separate smooth rating-scales.

Galati and Lavelli (1997) assumed that "the more the decoders' interpretation of a signal [i.e. *an infant's expression*] agree, the more the meaning of that stimulus [i.e. that expression] is clear and unambiguous" (p. 65). The decoders' agreement for the smooth scales increased with the infant's ages. In other words, infants' faces become easier to read from birth to three months old – which is the range of greatest interest for infant psychophysics.

7.5 The watcher-infant team: look duration in forced-choice preferential looking

Readers might object that inferring an infant's *feelings* in response to a sensory stimulus is not the same thing as inferring whether the infant attended to the stimulus or not. But inferring what the infant attends to can involve other confounds, as follows. Hansen and Fulton (1981) use Teller's (1979) forced-choice preferential-looking method to test a different infant at each of 2, 4, 8, 12 and 18 weeks of age. A blue dot was shown on a red background in darkness, on either the left or right side, and a watcher (aided by infra-red viewing equipment) judged whether the infant looked toward the left or the right. "Sensitivity" to the blue dot, thus obtained, increased with age; the infant who was 18 weeks old even achieved the known adult degree of sensitivity. This might be hastily interpreted as proof that detection thresholds drop with increasing infant age. However, Colombo (2002) reviewed the literature on visual behavior by infants, and found that look *duration* to visual stimuli rises over the period from birth to 7 weeks, and then falls again, stabilizing by roughly 20 weeks. If the Hansen and Fulton (1981) watchers – and those in auditory studies too – are judging attentiveness by gaze, how then can they be confident in their judgments, given Colombo's (2002) findings?

8. Summary and conclusions on infant "detection thresholds"

Infants are difficult subjects for psychophysical stimulus-detection or stimulus-discrimination tasks, in which a decision must be made about a stimulus, such as "it was barely visible" or "it was louder than another sound." Adults can indicate such decisions unambiguously; infants cannot, and hence in-laboratory watchers must *infer*, from infants' behavior, whether the infants saw or heard a particular stimulus.

This modern "infant psychophysics" started with studies of the visual system. Fantz and colleagues inferred the visual acuity of infants by recording how long and how often an infant fixated each of two alternatives, a striped pattern (grating) and a plain gray comparison. Soon, this "preferential looking" method was adapted for hearing studies. The stimuli could, for example, be "white" (i.e. broadband) noise or single-frequency tones or voices or musical notes. Each stimulus was presented to a left-side or right-side loudspeaker. Watchers inferred which loudspeaker the infant attended to. Indeed, the watchers even inferred whether the infant heard the stimulus *at all*, based on "widening or moving the eyes," "a decrease or cessation of activity", and "looking at the observer", among other cues.

Further changes were made, for testing visual acuity, by Teller and her colleagues. They presented a grating on one side or the other of a center point. Teller's watchers declared which of two directions the infant looked, a procedure called two-alternative forced-choice. Unlike earlier studies, the watcher was told whether their inference was correct or incorrect. Percentages-correct could then be plotted versus the width of the stripes in the grating, yielding a set of points, the psychometric function. These resembled psychometric functions found earlier by Fantz and colleagues, insofar as they had remarkably shallow slopes as compared to those of adults.

Yet further changes were made by Lynne Werner Olsho (later L.A. Werner) and colleagues, in the course of extending Teller's technique to *auditory* stimulus detection in infants. Instead of Teller's two- (or more) interval scheme, Werner and colleagues use a one-interval scheme in which the stimulus is either presented or not, which is inferred by the watcher from the infant's behavior. The watcher is told whether or not they are correct. The watcher's judgments are based on "eye movements," "eye widening and other changes in facial expression," "changes in activity level", etc., although sometimes the watchers simply rely upon their intuition. When the stimulus is presented *and* the watcher correctly indicates so, then a mechanical toy is revealed to the infant to psychologically reinforce the infant's response. When possible, psychometric functions for infants' detection of the stimuli are built. Those functions prove to be relatively shallow in slope.

The method of Werner and colleagues is still the standard for psychophysical testing of infants. But when it is scrutinized from a second-order-cybernetics viewpoint, incongruities arise. First, it is the watcher-infant duo who perform the detection/discrimination task, not merely the infant. The next crucial step, data analysis, is done by the rest of the laboratory. It is the whole laboratory, therefore, using the infant as a blunt probe, which produces psychophysical thresholds. Further, Werner and colleagues inform the watcher of the correct answer, which trains the watcher to "read" the infant. But from the infant's point-of-view, sometimes a reward appears (a mechanical toy activates), and sometimes it does not. Why?

There are yet further complications. Cues from the infant may differ by stimulus intensity, hence the infant's response to stimuli that it finds "quiet" may be indistinguishable from no response at all. Also, expressiveness may differ across infants. What one watcher takes to be moment-by-moment evidence of stimulus-detection by the infant might differ from what another watcher believes. In fact, some pre-Werner studies of infant hearing employed *two* watchers for each infant, unlike the Werner lab (and Teller and

Fantz in vision). Some studies even examined the mutual *agreement* of watchers. However, including more watchers does not increase the credibility of the basic method; whereas having a single watcher incorporates that watcher's prejudices.

Infants' stimulus-detection thresholds are empirically sought not only for their current presumed usefulness but also to examine their change over time. However, stimulus-detection thresholds reflect the watcher's ability to infer what the infant is attending to; therefore, if infants' *responses* become easier for the watcher to read with infant maturation, then any interpretation of change in the infant's *abilities* is confounded. Further, the infant's gaze is used as a cue to whether the infant detects the stimulus, but gaze duration may be a nonlinear function of infant age.

Workers in infant psychophysics have neglected an important second-order cybernetics emphasis, namely, the role of the observer. Consequently, suspicious methods have propagated, with a commensurate accumulation of questionable data. All of this occurs at the taxpayers' expense. Altogether, infant psychophysics has proven to be too resilient for anybody's good.

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