Why not both? Using multiple measures to improve reliability in infant studies

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Abstract

To increase reliability in infant experimentation, Byers-Heinlein et al. (2022) suggest six practical solutions. Here I add a seventh solution, which is recording multiple measures from the same infant and trial. Recording multiple measures is relatively easy to implement in many cases, and has additional advantages. I survey several ways to accomplish this, and recommend preregistering hypotheses and analyses plans beforehand to avoid adding researcher's degrees of freedom. Multiple measurements are complementary to Byers-Heinlein et al.'s (2022) solutions and should be used in tandem with them to further the quality of research in the field.

Highlights:

- To increase reliability, infant researchers can record multiple measures from the same infant and trial.
- For example, when measuring infant surprise, they may code total looking time, as well as social looks to the caregiver.
- Multiple measures do not replace other solutions for reliable data collection, they complement them.

Byers-Heinlein et al. (2022) rightfully point out, and demonstrate, the importance of examining and improving reliability in infant experimentations. They outline six possible solutions, ranging from the practical, which many researchers can adopt off-the-shelf (e.g., adding more trials by increasing infant engagement or by adding pauses within the experiment), to the more general improvement to the field at large (e.g., calculating and reporting reliability of measures). Here, I want to suggest another solution which has to do with something many researchers can adopt with almost no added effort - measuring responses with several measures at the same time.

In infant studies we sometimes examine a construct that can be measured with different behavioral measures. For example, surprise can be measured with ERPs (e.g., Berger et al., 2006), pupillometry (Zhang & Emberson, 2020), total looking time (e.g., Skerry & Spelke, 2014, but see Paulus, 2022 for a recommendation not to use this measure), and social looks to the caregiver (Dunn & Bremner, 2017). If a researcher is already collecting looking-time data using a closed-circuit camera, or an online video-conferencing tool (e.g., Kominsky, 2019), they may as well code the number of times the infant turned to their parents. If the researcher is working with an eye-tracker, which has better temporal and spatial resolution, they might as well collect pupillometry data¹.

Surprise is not the only construct which can be measured with multiple measures within the same trial. Hendrickson et al., (2015) measured 16-month-olds' vocabulary size with the Computerized Comprehension Test (Friend & Keplinger, 2008). In addition to recording infants' touches of the named target images, they also recorded gaze data. They found that infants who were faster to look to the target were also more likely to touch the correct images.

It has previously been recommended to use multiple measures in different research fields, such as in teacher evaluation (Martínez et al., 2016) and anxiety in mice (Henderson et al., 2004). Likewise, Kagan et al. (2002) claim that using multiple measures in personality and psychopathology assessment can help discover subtle differences that cannot be identified with a single measure (in this case self-reports). They claim that the same phenotype can have different temperamental origins - discriminated by adding physiological measures. Henderson et al. (2004) recommend analyzing composite measures that tap into measures common to all behavioral tests. In this respect, researchers should take care to ensure that all measures indeed tap into a common construct. Looking-time measures in infants may tap a novelty/familiarity preference as well as surprise in the face of unexpected scenes, and these constructs should be de-confounded with care (Jackson & Sirois, 2009).

¹ Note that Jackson & Sirois, 2009 found no correlation between these two measures when factorially comparing possible/impossible and novel/familiar events, claiming pupillometry is complementary but not equivalent to overall looking time.

Composite reliability can be expected to increase when a researcher adds more indicators of the same construct. However, another aspect of measurement which should be taken into consideration when using multiple measures is their individual reliability. Unreliable measures combined in an analysis may place upper bounds on the reliability of composites. Martínez et al., (2016) found that the way to use composite scores that best maximize reliability in teachers' assessment was using optimal reliability composites (Wang, 1998). Such a composite can be used even without prior knowledge of the reliability of the measures, by assigning more weight to tests that show small variance but higher covariance with the other measures (see Wang, 1998, for a formal model and equations).

The idea of using multiple measures has recently been advocated in infant studies as well. LoBue et al., (2020) claim that using multiple outcome measures can help disentangle different explanations for the same phenomenon. For example, one often discussed problem with looking-time data in infant studies is the expectation for novelty vs. familiarity preference (Aslin, 2007). Longer looking times are sometimes interpreted as a preference for novelty on the side of infants, whereas in other times, infants tend to look longer at familiar stimuli, suggesting they prefer familiarity. The conditions under which we can expect a novelty vs. familiarity preference are much discussed but poorly understood. Some researchers are now trying to more systematically examine when we can expect a novelty vs. familiarity preference in infants' looking times (see a registered report by Bergmann et al., 2019; and work in planning by Zettersten et al., under the ManyBabies umbrella). However, for the moment at least, collecting multiple measures can provide additional information about which construct we are actually tapping. Using multiple measures *from the same trial* can also help guard against transient errors (e.g., an infant was distracted during a specific trial, see Wiernik & Dahlke, 2019). While these are some of the advantages of collecting multiple measures, LoBue et al., (2020) do warn about one danger of using multiple measures - "the garden of forking paths".

A researcher collecting multiple measures has more researcher's degrees of freedom, which may increase the chances of the use of questionable research practices such as p-hacking. P-hacking and other questionable-research practices are not a problem unique to infant research (e.g., Simmons et al., 2011), however, some challenges having to do with overcoming them *are* unique to our field (see Havron et al., 2020). Recording multiple measures affords a researcher flexibility in data analysis. Will the researcher use the two measures separately and measure their convergence? Will the researcher combine them into one composite measure, and how will this combination be done (e.g., does every measure receive the same weight)? A researcher might also only report the measure "that worked", or report both, but post-hoc claim they hypothesized one will be more reliable than the other. All these risks can be avoided by preregistering one's study (see Havron et al., 2020 for a practical guide). In a preregistration, a researcher declares in advance their analysis plans, as well as their hypotheses,

reducing the risk of any post hoc decisions. This does not prevent the researcher from adding exploratory analyses and making post hoc claims - but it helps them frame them as such. For example a researcher may preregister a composite analysis, but then post hoc also examine each measure separately, and claim that the results suggest that one measure is more sensitive than the other, and that future studies should examine this.

Which analysis methods should a researcher use? This would have to do with the specific measures and constructs in question. As Byers-Heinlein et al. (2022) point out, we have reliability data for only a small subset of tools we use in our studies. If reliability data are available for your selected measures, it might be wise to assign more weight to the more reliable one. If different measures are taken at different levels (e.g., one at the trial level, and one only once per infant), they should probably not be combined, but analyzed separately and compared in one way or another. LoBue et al., (2020) recommends, when applicable, using multiple outcome measures as indicator variables of a latent variable (*the structural equation modeling*, SEM, approach). The main drawback of the SEM approach, however, is that it requires large samples - which are not common in infant research. Another way to analyze these measures is using mixed models with random intercepts for participants and items. In these models, each measurement is an observation, but the model takes into account the fact that two observations “come from” the same trial and participant (Baayen et al., 2008). While the use of mixed models might be new to some infant researchers, under certain conditions, these can be equivalent to the more familiar Cronbach’s Alpha (see Bravo & Potvin, 1991 for a formal model; Cronbach, 1947). If a researcher uses a model with a random intercept for participant (and possibly item), the Interclass Correlation Coefficient for participant is equivalent to the average item intercorrelation. There are advantages to fitting a mixed effects model instead of computing a composite. For example, a mixed effects model can better handle variations in numbers of measurements across participants (or measures, if one trial only has one type of measure); one can model random slopes to examine the stability of relationships with other variables across measurements; and measure within-participant factors (Brenton M. Wiernik, personal communication, January 30, 2022).

To conclude, collecting multiple measures from the same participant, and especially during the same trial, can help increase the reliability, validity, and insights infant researchers gain into their research questions and theories. This is also a relatively easy solution to implement in many cases. The use of this solution should not replace other solutions proposed by Byers-Heinlein et al. (2022). For example, the reliability of each measure (and their combined reliability) should, when possible, be calculated and reported. Multiple measurements can be seen as complementary to

Byers-Heinlein et al.'s (2022) solutions and can be used in tandem with them to facilitate our understanding of infants behavior, and improve the quality of research in the field.

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