

Findings of Addition and Subtraction in Infants Are Robust and Consistent: Reply to Wakeley, Rivera, and Langer

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Findings showing numerical computation abilities in infants are considerably more robust and consistent than Wakeley, Rivera, and Langer suggest. All the interim replication attempts have successfully replicated my original findings. Possible reasons for Wakeley et al.'s failure to replicate are discussed.

INTRODUCTION

In Wynn (1992a), I reported findings that young infants could determine the outcomes of simple addition and subtraction operations; across three experiments, 5-month-olds looked longer at numerically incorrect than correct outcomes of addition ($1 + 1$) and subtraction ($2 - 1$) situations. In their article in this issue, Wakeley, Rivera, and Langer present a failure to replicate these findings. Based on these results as well as those of other experiments, they conclude that infants' ability to compute results of simple additions and subtractions is fragile and inconsistent.

DISCUSSION

In fact, the findings reported in Wynn (1992a) are highly robust and consistent. All attempts at replication have found the same pattern of results. Two such studies compared 5-month-olds' looking times to outcomes of 1 and 2 objects following either a $1 + 1$ event or a $2 - 1$ event, and found, as did Wynn, a significant difference in outcome preference across the two events (Koechlin, Dehaene, & Mehler, 1997; Simon, Hespos, & Rochat, 1995). In each of these publications, the original finding was replicated both in a "standard" condition similar to that of Wynn, and in a second condition employing a substantive variation from the original Wynn study. Two further studies, in two experiments each, showed infants $1 + 1$ addition situations and found that infants looked longer at incorrect than correct outcomes (with 10-month-olds, Baillargeon, 1994; with 8-month-olds, Uller, Carey, Huntley-Fenner, & Klatt, 1999). Collectively, these studies comprise eight experiments, from four independent laboratories, successfully replicating the Wynn 1992

findings—which were themselves obtained across three experiments in the original report.

As Wakeley et al. (2000) discuss, some studies have reported failures of infants to discriminate numerically correct from incorrect outcomes to addition and subtraction events, but these studies have tested other abilities, presenting infants with different events from those in the above experiments. The failures reported suggest possible limitations to (1) the set sizes that infants can accurately operate over (Baillargeon, 1994; Wynn, 1995), (2) the number of mental "updates" infants can perform on an unseen set (Baillargeon, 1994; Uller et al., 1999), and (3) the numerical values that infants can represent (Wynn & Chiang, 1998). (It must be noted that these failures are themselves robust and consistent, each having been replicated one or more times, and *each obtained with the exact same stimuli and procedures that in other conditions elicited successful performance by infants.*) These kinds of limitations speak to theories of the mental processes underlying infants' expectations, not to the robustness or consistency of the original findings. I give two brief examples. First, on one theory of infants' numerical competence (Gallistel & Gelman, 1992; Wynn 1992b, 1998), the mental mechanism for number can represent positive integer values only, not other numerical values such as zero. Wynn & Chiang's (1998) finding that infants fail to detect an incorrect outcome to a $1 - 1$ event (which should result in zero objects) provides support for this theory. Second, Uller et al. (1999) propose that infants are operating over representations of specific individual objects, not of *number* of objects; infants' failure in a situation requiring them to make multiple "updates" to a scene without perceptual confirmation provides support for this theory. These issues are currently under heated debate, with considerable differences of opinion as to the best explana-

tion(s) for the observed findings (see, e.g., Uller et al., 1999; Wynn, 1998). But the discussion centers on the best theoretical account for the pattern of successes and failures observed, not on the reliability of the findings.¹

To collapse these successes and failures together and conclude that infants' performance is fragile and inconsistent is neither informative nor accurate. To do so not only masks the consistency of both successful and unsuccessful performance by infants, but also misses the increased richness and precision of theories of competence that result from taking into account the specific pattern of successes and failures. Consider an analogy: Humans can see in the light, but not in pitch-black. And we can see a penny when it is 4 feet away, but not when it is 4 miles away. To conclude from this that humans' ability to see is fragile and inconsistent would miss the significance of a highly informative pattern of performance.

Given the consistency of other replications, a plausible explanation for Wakeley et al.'s negative results is procedural. A number of differences between Wynn (1992a) and Wakeley et al. may have contributed to the discrepant results. I will briefly mention three of them. First, in Wynn, an experimenter determined the start of a new trial, taking into account the infant's attentiveness, whether the infant needed a brief break due to fussiness, and so on; in Wakeley et al., a computer program rigidly dictated the beginnings of trials. Second, in Wynn, the experimenter adding or subtracting the object could see the baby, and so ensure that infants always saw the complete operation. In Wakeley et al., the experimenter could not see the baby, raising the possibility that infants might not always have seen the complete operation from beginning to end. Third, there may have been significant differences in the criteria used for participant exclusion in Wakeley et al. compared with other studies. In Wakeley et al., the percentage of total infants tested who were excluded due to fussiness across the three experiments was 10%, much lower

¹ One further experimental finding bears comment. Moore (1997) showed 5-month-olds $1 + 1$ or $2 - 1$ situations schematically depicted by nondenotative, two-dimensional geometric shapes moving across a computer screen; only his female participants showed the pattern of looking times of Wynn's (1992a) participants. It is hard to interpret the null results of the male infants, given that the stimuli were not enduring material objects that should continue to exist once out of sight. It may be that the females but not the males were inferring a three-dimensional situation from the input. Other studies have also found successful performance at younger ages in female infants than in males, possibly due to different rates of visual development in the sexes (Baillargeon & DeVos, 1991).

than that excluded in Wynn (16%), Koechlin et al. (20%), Simon et al. (22%), and Uller et al. (22%). This suggests that higher levels of fussiness may have been tolerated in Wakeley et al. than in the studies that obtained positive results—and, as fussiness correlates inversely with attentiveness, infants in Wakeley et al. may have been less interested in the events than were participants in other studies. Lower levels of attentiveness in Wakeley et al. could well account for infants' lack of discrimination between correct and incorrect outcomes.

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