FORGETTING AND ENCODING AS SOURCES OF ERROR IN A STUDY OF CHILD VACCINATION

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1. Introduction

Two national surveys monitor childhood vaccination coverage rates--the National Immunization Survey (NIS) and the National Health Interview Survey (NHIS). A key estimate derived from both surveys is the proportion of children who have received all their recommended vaccinations by the age of two. Both surveys solicit information from adult respondents--typically, the parents of sample children.

Even conscientious parents may have difficulty in answering detailed questions about their children's vaccinations. Currently, children are supposed to have received at least 14 doses of five different vaccines by their second birthday. The five vaccines are for polio; measles, mumps, and rubella (MMR); diptheria, tetanus, and pertussis(DTP); hepatitis B (Hep B); and Haemophilus influenzae b (Hib). A vaccine for chicken pox will soon be added to this list. The names of the diseases the vaccines are intended to prevent are long and difficult to pronounce and the diseases themselves may be unfamiliar to many parents. Fortunately, many pediatricians provide parents with a vaccination card that records the vaccinations their children have received. Respondents in both the national vaccination coverage surveys are encouraged to consult these cards in reporting about sample children. Despite these efforts, approximately half of the respondents provide vaccination data without the aid of the cards or other records.

The accuracy of these unaided reports in the national surveys is still being explored. However, earlier evaluations of the accuracy of parental responses to questions about vaccinations suggest that there is considerable error in these reports. For example, Goldstein and her colleagues found that parents overreported the number of vaccinations their children had received (Goldstein, Kviz, & Daum, 1993). Across a number of studies that compare parental reports with provider records, overreporting of vaccinations appears to be the rule (Goldstein et al., 1993; Hawe, Wilson, Fahey, Field, Cunningham, Barker, & Leeder, 1991; Kalsbeek, Weigle, Allred, & Liu, 1991; Killewo, Makwaya, Munubhi, & Mpembeni, 1991; McKinney, Alexander, Nicholson, Cartwright, & Carrette, 1991), although a few studies also find underreporting (Gergen, Ezzati, & Russell, 1988; Valadez & Weld, 1992).

The two studies described here investigate sources of error in parents' reports about their children's vaccinations and explore methods for improving the accuracy of those reports. The specific hypotheses they test are partly derived from a model of the process of answering questions. Over the last 15 years or so, several models of the survey response process have appeared (e.g., Cannell, Miller, & Oksenberg, 1981; Strack & Martin, 1987; Tourangeau, 1984). Although the models differ in many particulars, they share the assumption that reporting errors arise in surveys because of problems in one or more of the underlying cognitive operations through which survey reports are generated. As applied to reports about children's vaccinations, these models point to five potential sources of error. First, some parents may never have encoded the relevant information in the first place. Several characteristics of vaccination episodes may discourage careful encoding: Vaccinations have become routine; the child may receive multiple vaccinations during a single visit to the pediatrician; the doctor or nurse may not take the time to identify the shots being administered during that visit; and parents may be too distracted to assimilate this information in any case. Second, parents may have difficulty understanding the vaccination questions when the survey interview is administered. Comprehension of the questions would seem to require that the respondents recognize the relevant terms (e.g., oral polio vaccine) and differentiate each vaccine from the others. Many parents probably lack the requisite background knowledge to understand the questions fully. Third, at the time of the interview, the respondent must recall information about each vaccine in question (unless he or she can retrieve this information from a vaccination card). Given the number of vaccinations and the similarity of the episodes in which they were administered, recall is likely to present a formidable challenge. Fourth, some respondents may simply report that their children have received all the recommended doses, and their judgment about this may be mistaken. Finally, some respondents may recognize that their children are not fully vaccinated but be embarrassed to admit this.

The current investigations focus on memory processes as potential sources of reporting error in vaccination surveys. (A future study will examine some of the other possible sources of error.) As in most investigations of memory, we assumed that the information in question had been initially encoded and stored in long-term memory; the key issue was thus how to prompt its retrieval when the survey questions were administered. Accordingly, our first study examined whether memory aids such as a medical history calendar or a card displaying the number of recommended doses for each vaccine could improve recall. Even assuming that parents were aware of each vaccination their child had received, the number and routine character of the vaccinations would encourage the formation of a "generic" memory, in which the details of the individual vaccinations would blur together (Means & Loftus, 1991; Smith, Jobe, & Mingay, 1991). The memory aids were an attempt to assist the respondents in reconstructing which vaccinations the children had actually received.

We were also concerned, however, that the initial encoding of information about vaccinations might be inadequate to permit accurate recall about individual vaccinations at the time of the survey interview. A number of studies have demonstrated the importance of initial encoding processes on subsequent retrieval (e.g., Anderson & Reder, 1978; Craik & Lockhart, 1972). In the limiting case, the trace left by the initial experience might be virtually nonexistent or inaccurate--parents may have only a hazy sense of the shots administered on a specific occasion or they may be completely mistaken about which shots their children received. To investigate this possibility, we conducted a second study that examined parents' initial encoding of information about vaccinations.

2. Study 1

Our first study examined two of the potential sources of reporting error. One involved retrieval failures, in which respondents are unable to distinguish different episodes in which the child received a vaccination. We thought that if memories for individual vaccination episodes had merged into a generic memory, a medical events calendar might help respondents to reconstruct the specific episodes (Means & Loftus, 1991). To test whether such a calendar might improve recall, half of the respondents in our first study were asked to record information about their child's medical providers, illnesses, and pediatric visits on a grid in which the columns represented the months of the child's life; the other half were not asked to use this calendar, but were administered a standard set of questions about their children's vaccinations.

The second potential source of error involved the use of flawed estimation strategies. Respondents who cannot retrieve information about individual vaccinations may attempt to answer the questions by estimating the number of vaccinations their children have received. These estimates may be based on easily retrieved information, such as the overall frequency of visits to the pediatrician. Based on the hythosesis that some answers are estimates, we sought to determine whether the answers might be improved if respondents had accurate information to anchor their estimates. We varied whether the respondents received a show card listing the five recommended vaccines and the number of doses recommended for each.

In addition, we examined whether answers were affected by the order in which the questions were asked. We varied whether questions concerning each vaccine came before or after a global question asking whether the child had received all the recommended vaccinations. We hypothesized that answers to the global item would be more accurate when that question followed the specific items than when it preceded them. When the global item came after the specific questions, the answers would, we thought, reflect a careful judgment based on the number of doses reported for each vaccine; by contrast, when the global item came first, the answers were likely to be based on a general impression. Half of the respondents received the global question first; the remaining half received that item after the questions about the specific vaccines.

2.1 Method

Sample. The respondents in the experiment were the primary caregivers of two- and three-year-old children that had attended a pediatric clinic in Chicago. The clinic provided NORC with a list of all two- and three-year-old children--ranging in age from 24 to 47 months--who were patients there. We sampled children from this list and randomly assigned them to experimental groups. We deliberately oversampled children who had not, according to clinic records, received all their recommended vaccinations.

The respondent to the interview was typically, though not always, the child's parent. In recruiting respondents to report about the sample child, we asked for the person who usually took him or her for visits to the doctor. Each respondent was paid $30 to come to NORC's Chicago office and participate in a 20 minute face-to-face interview. Interviews were completed with 221 respondents. A very high percentage of them, 94%, were mothers or female guardians of the sample child; another 5% were grandparents, and the remaining few were fathers, aunts, or uncles. The clinic serves a poor area in the city of Chicago. About 70% of the respondents had never been married, and the remaining 30% were split evenly between currently and formerly married respondents. About 85% of the respondents had completed high-school, and another 46% had attended college.

Procedure. The main dependent variables were the accuracy of the respondents' reports about their children's overall vaccination status and the accuracy of their reports about each specific vaccine. These dependent variables were derived by comparing the respondents' answers to the questionnaire items with the child's medical records. The experiment included three independent variables--whether a calendar was used to prompt recall on the vaccination questions, whether a showcard provided anchoring information about the number of doses recommended for each vaccine, and whether the item on the child's overall vaccination status preceded or followed the questions about each vaccine.

The key questionnaire items were the same vaccination history questions used in the two national immunization surveys. This standard set of question first asks respondents whether the child had ever received any vaccinations either in the form of shots or drops. If the child had ever received a vaccination, respondents are then asked whether the child had received each specific vaccine (DTP, polio, MMR, Hib, and Hep B), and, if so, the number of doses they had received for each one. Besides including the standard questions about the five recommended vaccines, we added similar items about vaccinations for smallpox, chicken pox, and pneumococcal disease; the children were unlikely to have received any of these vaccinations, and these items were included to determine whether respondents had a general tendency to overreport vaccinations. Finally, the standard vaccination history questions include an item assessing the child's global vaccination status ("In your opinion, has __________ received all of the recommended shots for his/her age?").

In addition to the vaccination history items, the questionnaire included items assessing the respondents' knowledge about vaccinations. For each vaccine, the respondent was asked what illness the vaccination was supposed to prevent and how many doses the child was supposed to have received by age two. Finally, the last section of the questionnaire collected basic demographic information about the respondent.

The experiment varied three factors. The first was whether the interview was calendar-aided. The calendar-aided questionnaire attempted to create a rich set of contextual and chronological cues to prompt accurate recall of the number and dates of each vaccination. Under this approach, respondents recorded health-related information on an event history calendar before they answered the standard vaccination questions. First, the respondent identified the child's source of medical care during each period of his or her life. Both the usual source of care (if there was one) and any other sources of medical care were noted on the calendar. Next, major events in the child's medical history, such as serious illnesses or injuries, were noted on the calendar, followed by specific visits to each caregiver. In the final step, respondents indicated whether vaccinations were given during each visit. After completing the calendar, the respondents were administered the standard questionnaire items. The calendar-aided questionnaires was contrasted with questionnaires that included only the standard vaccination questions. The second experimental variable was whether the respondent was presented with a showcard that listed each vaccination and the number of doses recommended by age two years. In half of the questionnaires, respondents viewed a showcard while answering the standard vaccination questions; in the remaining half, respondents answered the vaccination questions without the aid of the showcard. The final experimental variable was the order in which global and specific vaccination questions were asked. In half the questionnaires, the global vaccinations status item came after the questions about the specific vaccines; in the remaining half of the questionnaires, the global item preceded the items on each vaccination series.

Collection of vaccination records data. At the conclusion of the interview, respondents were asked to list all of the medical providers from which the child had received medical care and to sign a permission from giving us access to the child's medical records. Any additional medical providers (besides the clinic from which the children had originally been selected) were contacted and asked to provide information about the vaccinations they administered to the sample child. We obtained completed medical records for 189 of 221 sample children. A NORC interviewer examined each child's medical record and recorded the dates when each vaccination was given.

2.2 Results

Overall accuracy. Two sources of information concerning the vaccinations each child had received were available--the questionnaire reports and the medical records. Respondents answered a global question, in which they indicated whether their child was up to date for all vaccinations, and they answered questions about each vaccine, indicating the number of doses the child received. Thus, based on the questionnaire data, children could be classified as being up to date for each vaccine (if the number of doses reported for the vaccine matched or exceeded the recommended number) or not up to date. Similarly, the child's up-to-date status could be determined from the medical records. From these classifications, we constructed four measures of the accuracy of the respondents' reports:

1) The false positive rate (the proportion of children classified as up to date based on medical records data who were reported as not being up to date based on the questionnaire);
2) The false negative rate (the proportion of children classified as not up to date based on medical records data who were reported as being up to date in the questionnaire);

3) The phi correlation between the questionnaire report and medical records regarding up-to-date status;
4) The net bias (the difference between the percent classified as up to date in the two data sources).

Table 1. Child's Vaccination Status and Respondent Accuracy Measures, by Vaccination

Vaccine	Up to Date	Accuracy Measure			
		Net Bias	False Negative	False Positive	Phi
Hepatitis B	45.3 (139)	0.7 (139)	50.8 (63)	43.4 (76)	0.06 (139)
DTP	71.6 (148)	-29.7 (148)	55.7 (106)	35.7 (42)	0.08 (148)
Polio	78.1 (155)	-28.4 (155)	47.1 (121)	38.2 (34)	0.12 (155)
HIB	80.8 (120)	-38.3 (120)	57.7 (97)	43.5 (23)	-0.01 (120)
MMR	82.5 (143)	16.8 (143)	0.0 (118)	96.0 (25)	0.18 (143)
Global Status	34.9 (189)	53.4 (189)	1.5 (66)	82.9 (123)	0.23 (189)

Note: Sample sizes on which each rate is based appear in parentheses. "Up to date" column shows the proportion receiving the recommended doses, according to their records.

Table 1 shows the overall levels of accuracy by vaccine and for the global status question. There is a significant relation between the child's actual status (according to the records data) and reported status only for the global status item ($\chi_1^2 = 10.11, p < .01$) and for the item on MMR ($\chi_1^2 = 4.75, p < .05$). However, even on those items, there are high levels of error in the respondents' reports. On the global status item, more than 80% of the respondents reporting about children who were *not* up to date according to medical records reported that the children had received all their recommended shots. Approximately 98% of the parents whose children were up to date according to the records reported that their children had received all their recommended vaccinations. Thus, the net bias on the overall status item is quite large (53.4%), with the reports biased in the direction of overreporting. Similarly, almost all the respondents indicated their children had received one dose of the MMR vaccine (which is all that is recommended), including 24 of 25 of the respondents reporting about children who had not received that vaccine according to their medical records.

Although responses to the global status and MMR questions show high rates of overreporting children as being up to date, responses to the questions about three of the four other specific vaccines show underreporting to be quite common as well. These four vaccines all require three to four doses. The false negative rates for these vaccines ranged from 47% for polio to 58% for Hib; that is, about half the respondents reporting about children who had (according to their medical records) received all the recommended doses for these vaccines reported fewer than the recommended number of doses. The false positive rates for these same four vaccines (ranging from about 36 to 44%) show that the number of parents who mistakenly overreport their child's status is also quite high. Chance levels of accuracy would yield false negative and false negative rates that do not differ significantly from 50%. In fact, for the four vaccines involving multiple recommended doses, the phi correlations, false positive rates, and false negative rates all indicate chance levels of accuracy. The only exception is the polio vaccine, with a false positive rate (38.2%) that is significantly below 50% (by a sign test).

Table 2. Accuracy Measures, by Vaccine: "Has[Child] ever received a __ shot?"

Vaccine	Received	Accuracy Measure			
		Net Bias	False Negative	False Positive	Phi
Hepatitis B	73.5 (189)	12.7 (189)	7.9 (139)	70.0 (50)	0.28 (189)
DTP	95.2 (188)	2.7 (188)	2.2 (179)	100.0 (9)	-0.03 (188)
Polio	94.7 (188)	2.7 (188)	2.8 (178)	100.0 (10)	-0.04 (188)
Hib	94.7 (189)	-23.3 (189)	27.9 (179)	60.0 (10)	0.06 (189)
MMR	81.0 (189)	7.9 (189)	9.2 (153)	80.6 (36)	0.13 (189)

Note: The sample size on which each rate is based is given in parentheses. "Received" column shows the percentage receiving the vaccine according to medical records.

The respondents, thus, are not very accurate in reporting how many shots the children received. Are they more accurate about whether the children had *ever* received the vaccine? Table 2 shows the accuracy of parents' responses to questions concerning whether their child had ever received a particular vaccine. Although respondents for children who had received a vaccine appear highly accurate (the false negative rates are generally below 10%), the rate of false positives is quite high (ranging from about 60 to 100%), indicating that regardless of whether the child had received a given shot, the respondents were prone to report that he or she had received one. We examined the overall relationship between respondents' reports about whether the child had ever received any doses of a particular vaccine and whether the medical records indicated at least one dose had been received. The relationship was significant only for the Hepatitis B vaccine ($\chi_1^2 = 15.12, p < .01$).

Questions on the smallpox, varicella (chicken pox), and pneumococcal vaccines were included to detemine whether respondents generally tended to overreport vaccinations their children had received. Sample children were very unlikely to have received any of these vaccines. (The smallpox vaccine is no longer administered in the United States, the varicella vaccine is just being introduced, and the pneumococcal vaccine is rarely given to children.) However, 24.3% of the respondents reported that the child received the smallpox vaccination, 30.2% reported the varicella vaccine, and 2.6% reported the vaccine for pneumococcal disease.

Overall, then, the data suggest that many respondents were uncertain about their child's vaccination status and had a strong tendency to respond that the child had received all the vaccinations they were asked about. This leads to overreporting on the global question and the questions concerning whether the child had *ever* received a particular vaccine. Because they were uncertain about the number of doses the child received, respondents reporting about up-to-date children often underreported and those reporting about children who were not up to date often overreported.

Effects of the experimental variables. The three experimental variables had little impact on respondents' accuracy. We carried out logit analyses examining the effects of the experimental variables on answers to the global questions and the questions on each specific vaccine. In these analyses, the dependent variable was the accuracy of the respondent's report about the child's up-to-date status. The independent variables were the presence or absence of the calendar, presence or absence of the showcard, and question order. In an additional set of analyses, the child's actual vaccination status was included as a fourth independent variable.

In the three-way analyses on accuracy, only one effect emerged as significant in the six analyses. It involved the reporting of Hib; for that vaccine there was a significant interaction between the calendar and the question order variable ($z = 1.98$, $p < .05$); no other main effects or interactions were significant for reports on Hib, the other four vaccines, or global vaccination status. Since these analyses tested a total of 42 main effect and interaction terms, the interaction effect for Hib reporting is quite likely due to chance.

The four-way analyses on accuracy of reporting showed that whether the child was up to date affected accuracy of reporting for the global question, MMR, and DTP ($z = 7.53$, $z = 7.10$, and $z = -2.05$, respectively). For both the global question and MMR, respondents were more accurate when the child was up to date according to the medical records (98.5% vs. 17.1% accuracy for global vaccination status, 100% vs. 4% accuracy for MMR); the opposite was true for DTP, where respondents were *less* accurate if the child was up to date (44.3% vs. 64.3%). The four-way analysis revealed few effects for the experimental variables. There was a significant showcard by up-to-date status interaction for accuracy of reporting on Hep B ($z = -2.65$, $p < .05$), and the same calendar by question order interaction for Hib reporting significant in the three-way analysis emerged again in the four-way analysis ($z = 1.99$, $p < .05$). Given the large number of potential effects tested for, we are not inclined to offer substantive interpretations for these two interactions.

Knowledge about vaccinations. One possible explanation for the respondents' low accuracy is their failure to encode the relevant information when the vaccines were given. Even if respondents knew the child had been vaccinated, they may not have been told by the physician or nurse what the vaccine was for. We tested this argument by comparing the reports of parents who demonstrated high levels of knowledge about vaccinations with those demonstrating low levels. A knowledge score which combined accuracy in naming the diseases the vaccines are intended to prevent and accuracy regarding the number of recommended doses was calculated for each respondent. The respondents answered four questions on the diseases prevented by the vaccines (we left out the polio vaccine), giving them an opportunity to name eight diseases. In addition, they answered five items on the number of doses recommended for each vaccine. Overall, then, respondents could give a total of 13 correct answers on the knowledge questions.

The respondents' knowledge was quite spotty. For DTP, 47% of the respondents were unable to name even one disease prevented by the vaccine; only 9% could name all three. Similarly, only 13% could state the disease prevented by the Hib vaccine. Performance on MMR was somewhat better, with 63% able to name at least one of the diseases the MMR vaccine prevents and 40% able to name all three. Perhaps because of its name, 78% answered the question about the Hep B vaccine correctly. Performance was also poor on the items assessing knowledge of the number of doses recommended for each vaccine.

Respondents were divided into two groups based on the median knowledge score. Respondents above the median in their knowledge about vaccinations gave more accurate reports than the less knowledgeable respondents, correctly reporting the child's status on an average of 2.6 out of the five vaccines (vs. 1.7 for the respondents below the median); $t\,(169.74) = -4.11, p < .01$.[1]

The effects of knowledge about vaccinations on the effectiveness of the calendar and showcard were tested in an analysis of variance. The dependent measure was the respondent's overall accuracy score, reflecting the number of vaccines (out of five) on which the respondent's report agreed with the medical records about whether the child had received all the recommended doses. In an analysis of variance with the experimental variables and knowledge level (high vs. low, as determined by a median split) as independent variables, only knowledge level was found to influence overall accuracy--$F\,(1, 172) = 15.94$, $p<.01$. That is, respondents with greater knowledge about vaccinations gave more accurate answers. Once again, accuracy was not influenced by the experimental factors.

Half of the respondents received a show card listing the vaccines and their recommended doses, and this should have improved their knowledge scores. Respondents who received the showcard were more accurate on the questions about the number of recommended doses for each vaccine (answering an average of 2.1 vs. 1.5 for no-showcard group); $t\,(187) = -2.45, p < .05$. As already reported, the showcard did not improve accuracy on the key vaccination history questions.

Strategies for recalling vaccination information. Respondents were asked to choose which of several strategies best described their approach to answering the vaccination questions. As Table 3 indicates, the most frequently cited strategy was that of recalling information from the vaccination card. Most respondents indicated that they had a vaccination card for their child (179 out of 189, or 94.7%). Those who had looked at their child's card more within the last week showed significantly better total accuracy scores than those who looked at the card more than a month ago-- $t\,(104.89) = 2.49, p < .05$. Table 3 also shows mean scores on the total accuracy measure by recall strategy. Accuracy scores differ significantly among respondents citing one of the five specific strategies (excluding the category of "other" strategies), $F\,(4, 179) = 5.30$, $p < .01$. Post-hoc Scheffe comparisons indicate a significant difference only among those choosing the first and second strategy listed in the table (recalling each doctor visit vs. recalling information from the vaccination card). Those respondents who said they relied on memory of the vaccination card reported their children's vaccination status more accurately.

We compared the number of respondents selecting each recall strategy in the calendar vs. no-calendar versions and showcard vs. no-showcard versions. Chi-square tests indicated a significant effect of the showcard on strategy ($\chi_4^2 = 21.99, p < .01$), but no effect of the calendar (χ_4^2 = 2.07). Specifically, respondents who viewed the showcard were three times more likely to state that they adopted the strategy of trying to recall whether their child had gone to all scheduled well-baby visits.

Table 3: Strategies for Recalling Vaccinations

Strategy	Number (%)	Mean accuracy
Try to remember each visit when a vaccination was given.	51 (27%)	1.6
Try to remember the child's shot card.	74 (39%)	2.7
Try to remember how many vaccinations the child was supposed to get.	21 (11%)	2.5
Try to remember what the doctor said.	18 (9%)	1.6
Try to remember whether the child went to all scheduled visits.	20 (11%)	1.8
Other strategy	5 (3%)	2.0

Note: Sample size equals 189; accuracy score is based on number of vaccines for which the parental reports agreed with the medical records.

2.3 Discussion

The most striking findings in Study 1 were the low levels of reporting accuracy and the effects of knowledge about vaccinations on accuracy. Overall, respondents performed barely above chance levels of accuracy in reporting the vaccination status of the sample children. The best predictor of accuracy was the level of knowledge about the vaccinations. It is likely that many respondents encoded little information about the vaccinations their children received at each visit to the doctor simply because they never learned much about the different vaccines and lacked the background knowledge needed to encode what happened during each visit. Procedural variations designed to prompt fuller recall--such as those tested in Study 1--are likely to fail when respondents have stored little information in memory in the first place. In Study 2, conducted at

[1] A separate variance estimate was used because a test for homogeneity of variances was significant, p < .01.

roughly the same time as Study 1, we examined parents' encoding and storage of information about the vaccines their children received.

3. Study 2

In the second study, we attempted to learn how accurately parents encode information about a vaccination episode and the extent to which this information becomes lost or distorted over time. Parents whose children had just received one or more vaccinations were interviewed as they left a vaccination clinic at a health maintenance organization in Oakland, California. The parents responded to a general question asking them to describe in their own words what treatments the child had received that day; they were also specifically probed about whether the child had received any vaccinations. The parents' reports were coded and compared with the clinic's records of the shots the child had actually received. This comparison provided a basis for assessing the accuracy of the initial encoding of information about the visit. To assess how this information was transformed in memory over time (as memories of one vaccination episode blend with memories of other episodes), we contacted the respondents again after ten weeks had elapsed. At the same time, we also interviewed a group of parents whose children had also been vaccinated at the clinic during the same period as the first group of respondents but who were not interviewed until ten weeks later; this comparison group allowed us to determine whether the initial interview affected the storage and retention of information in memory.

3.1 Method

Sample. The sample for this study consisted of 103 parents whose children were patients at a pediatric clinic in Oakland, California. All of the children were less than seven years of age. Of the parents, 81% were mothers and 19% were fathers. The sample was divided relatively evenly by race with 39% white, 29% black, 14% Hispanic, 16% Asian, and 3% other races or ethnicities. Respondents were highly educated, with 97% having completed high-school, and 46% having attained a college degree.

Data were collected in two waves. During the first wave, two interviewers were stationed outside of the clinic exit. The interviewers stopped parents who emerged from the clinic and asked if they would participate in a survey; 103 agreed to take part. About two-thirds of the parents--70--were asked about their child's medical visit, and also were asked for information that would enable us to contact them in the future. The other third--33 parents--were asked only for the locating information. In addition, every respondent was asked to sign a consent form giving the researchers permission to obtain information from the child's medical record.

Wave 2 data were collected by telephone ten weeks after the initial data collection. Eighty of the 103 respondents were successfully contacted and reinterviewed. Of the 80, 54 had completed the full Wave 1 interview and 26 had been asked only for locating information during Wave 1. All 80 of the Wave 2 respondents were asked about the medical treatment the child received during his or her doctor visit ten weeks earlier. The same basic questionnaires were used in both interviews (with minor changes to reflect the passage of time).

Coding of the parents' data. We counted a parent as reporting a particular vaccination even if the respondent only named one component of the vaccine (e.g. "measles" for MMR). If a parent had indicated that the child received the combination Hib/DTP (or "Tetramune") shot, both Hib and DTP were counted as having been reported.

The questionnaire gave respondents two opportunities to report vaccinations--first, in response to a general question that asked what had happened during the medical visit that day ("To start off, would you tell me in your own words what happened during the child's visit today?") and later in response to more specific questions ("Did ______ get any shots today? What were the shots for?"). We refer to answers to the general question as free recall responses and answers to the more specific questions as cued recall responses. The basic accuracy analyses combine the data from both questions; if a parent reported the child had received a vaccine in response to either item, we counted the parent as reporting the vaccine.

3.2 Results

Free vs. cued recall questions. We compared answers to the more general free recall item with those to the subsequent cued recall question that specifically mentioned shots. We found virtually no differences between the two sets of responses. For example, 36 people reported the polio vaccine in response to the general question, and 38 reported it in the more specific question. The phi correlations between the two types of questions were highly significant for all five vaccines, with the weakest one being .71 for Hib. Therefore, we combined responses to the two questions in the remaining analyses.

Wave 1 accuracy. The focus of the analysis was on the accuracy of the parent's reports. We constructed four measures of accuracy, comparable to those constructed for the first study, by comparing the parent's report with the medical record of what had happened during the visit. As in Study 1, the accuracy measures were the false negative rate for each vaccine (the proportion of children who received the vaccine according to the record but whose parents did not report it), the false positive rate (the proportion of children who did not receive the vaccine but whose parents reported it), the phi correlation between the parent's report and the medical record, and the net bias (the difference between the proportion of children who received the vaccine according to the medical records and the parent's report).

The results indicate that, even immediately after the vaccinations had been administered, most parents had little idea about which vaccinations their children had received that day. The children had received an average of three vaccines during their visit to the clinic. The parents, on average, correctly named only half of these; across the five shots, the false negative rate averaged 49%. Parents also occasionally reported shots their children had not received (overall, the false positive rate was 18%), but, on the whole, underreporting seemed more prevalent than overreporting. There was a significant relation between whether the parent reported the vaccine and whether the child had actually received it during the visit for DTP ($\chi_1^2 = 7.01, p < .01$) and polio ($\chi_1^2 = 12.17$, $p < .01$), and a marginally significant relation for MMR ($\chi_1^2 = 3.81, p < .06$).

Table 4. Child's Vaccination Status and Respondent Accuracy Measures, by Vaccine : Wave 1

Vaccine	Received	Accuracy Measure			
		Net Bias	False Negative	False Positive	Phi
Hepatitis B	85.7 (70)	-41.4 (70)	51.7 (60)	20.0 (10)	.20 (70)
DTP	82.9 (70)	-31.4 (70)	41.4 (58)	16.7 (12)	.32 (70)
Polio	80.0 (70)	-24.3 (70)	33.9 (56)	14.3 (14)	.42 (70)
HIB	74.3 (70)	-64.3 (70)	86.5 (52)	0.0 (18)	.20 (70)
MMR	4.3 (70)	17.1 (70)	33.3 (3)	19.4 (67)	.23 (70)

Note: Total sample size equals 70; the sample size upon which each rate is based is given in parentheses.

Table 4 shows the four accuracy measures by vaccine for the Wave 1 reports. The type and magnitude of the reporting errors differed greatly by vaccine. The four vaccines that most of the children had received--Hepatits B, DTP, polio, and Hib--were generally underreported, with the net bias ranging from -24.3% to -64.3%. This tendency toward underreporting of these four vaccines was also apparent in the high false negative rates, which ranged from 33.9% for polio to 86.5% for Hib, indicating that, when the child received a vaccine, many parents failed to report it. Averaging across the five vaccines, parents were about as likely *not* to report a vaccine their child had received as to report it (the mean false negative rate was 49.4%).

Hib was the most underreported vaccine of all, which is consistent with the results of the first study. Hib tends to stand out from the other vaccines in terms of its net bias, false positive, and false negative rates. The extreme underreporting apparent in the negative net bias is a result of only 10.0% of parents reporting Hib, although 74.3% of the children received it. This vaccine also had a false positive rate of zero. The tendency not to report Hib--whether or not the child actually received it--could be due to its complicated name and the unfamiliarity of the disease (a form of meningitis). The tendency to underreport was apparent for all the vaccines except MMR. The MMR vaccine was administered much less often than the other vaccines and, perhaps as a consequence, was overreported rather than underreported; only 4.3% of the children received the vaccine and 21.4% of the parents reported it. This resulted in a false negative rate of 33.3% (when the children received the vaccine most parents reported it), but a false positive rate of 19.4%. Another possible reason that the pattern of reporting for MMR is different from that for the other vaccines could be the same reason that the knowledge scores from the Study 1 were high for this vaccine: parents have a greater familiarity with the vaccine and the diseases it prevents.

We tested the hypothesis that the reporting errors for each shot were not random, but were biased in the direction of either over or underreporting. We used McNemar tests for this purpose, comparing the sizes of the two off-diagonal cells; this yields a z statistic, with positive values indicating overreporting and negative values indicating underreporting. Significant underreporting was found for every shot except MMR (all p's $< .01$), which was significantly overreported ($z = 3.21$). Overall, then, only two vaccines (DTP and polio) were reported with better than chance accuracy and even these two were systematically underreported.

We also explored whether the accuracy of reports varied according to the respondent's characteristics. We compared the performance of respondents reporting about first-born versus later-born children, only children versus children with siblings, and children less than two years old versus older children; we also compared mothers with fathers, and respondents with different levels of education. Only one of the comparisons yielded a significant result--the false negative rate was lower for children with no siblings than for children with siblings (mean false negative rate of 42% vs. 56%; $F(1, 66) = 4.25, p<.05$).

Wave 2 accuracy. After a ten week period, parental reports were only slightly less accurate than they were in Wave 1. In the second wave, reports about DTP and polio were still significantly related to whether the child had received these vaccinations (for DTP, $\chi_1^2 = 8.54$, $p< .01$; for polio, $\chi_1^2 = 4.75$, $p< .05$). The average false negative rate in Wave 2 was 54.6%, only a slight increase over the 49.4% average rate in Wave 1. The average false positive rate across the five vaccines--14.1% in Wave 1--rose only to 18.2% in Wave 2. These increases in the error rates may reflect some memory loss.

Table 5 reveals that differences in accuracy across the types of vaccines are just as apparent in Wave 2 as they were in Wave 1. For the four shots received by most of the children (Hepatitis B, DTP, Polio, Hib), underreporting was common and the net biases were negative. (This is partly due to the fact that so many children received these four shots, creating more opportunities for false negatives than for false positives.) For MMR, which few of the sample children actually received, overreporting is the rule.

Table 5. Child's Vaccination Status and Respondent Accuracy Measures, by Vaccine : Wave 2

Vaccine	Received	Accuracy Measure			
		Net Bias	False Negative	False Positive	Phi
Hepatitis B	86.3 (80)	-55.0 (80)	65.2 (69)	9.1 (11)	.19 (80)
DTP	80.0 (80)	-35.0 (80)	46.9 (64)	12.5 (16)	.33 (80)
Polio	80.0 (80)	-18.8 (80)	32.8 (64)	37.5 (16)	.24 (80)
HIB	73.8 (80)	-56.3 (80)	78.0 (59)	4.8 (21)	.20 (80)
MMR	2.5 (80)	25.0 (80)	50.0 (2)	26.9 (78)	.08 (80)

Note: Total sample size equals 80; the sample size upon which each rate is based is given in parentheses.

Comparison of Wave 1 and Wave 2. We also examined the consistency between Wave 1 and 2 reports for the 54 respondents who completed full questionnaires in both waves. For three of the five vaccines, the phi correlation between reports in the two interviews was statistically significant (DTP, phi = .52; polio, phi = .59; MMR, phi = .39; $p< .01$ for all comparisons). In fact, the phi correlations are generally higher than those in Tables 3 and 4. For four of the five vaccines, there was greater consistency between the parents' reports in the two waves than there was agreement with the medical records in either wave. The exception was Hib, where the correlation across waves was only .14.

To determine whether there was an overall direction to changes in the respondents' reports between waves, either in the form of forgetting vaccinations that had been reported previously or of reporting new vaccines not reported previously, we carried out McNemar tests for each vaccine. The results were not significant; there was no consistent pattern to the changes between waves.

4. Discussion

The results from the Study 2 indicate that the major source of reporting error is failure to accurately encode what happened during the vaccination episode rather than failure to retrieve that information later on. As they left the pediatric clinic minutes after the child had been vaccinated, only 12 respondents out of a total of 70--about 17%--reported all of the vaccinations their children had received and only those vaccinations. Ten weeks later, the proportion declined to 11%; only 9 out of 80 Wave 2 respondents accurately described the vaccinations their children had received. In both waves, the respondents consistently underreported all of the vaccines that involve multiple doses and systematically overreported the one vaccine (MMR) for which only one dose is recommended. In both interviews, the relation between which shots were reported and which the child received was little better than chance. Apparently, many respondents were aware that the child received one or more vaccinations during the visit, but were simply guessing about which ones. None of the characteristics of the respondents or of the sample children was strongly related to accuracy of reporting in Study 2.

It is possible that a recognition test, in which the names of vaccines were presented to respondents, would have yielded a more positive picture of the level initial encoding of vaccination information. Recognition tasks impose fewer demands on retrieval than either the free recall or cued recall items that were included in Study 2. Still, no difference was evident between the responses to the free and cued recall items, even though free recall items place greater demands on retrieval than cued recall items.

The results of the first study provide further evidence that the inaccuracy of parental reports arise at encoding and not at retrieval. The standard questions used in Study 1 function as a recognition test; respondents are asked whether their child received each particular vaccine ("Has [child] ever received a DTP shot?"). Yet the respondents still demonstrated poor recall accuracy. They seemed to have considerable difficulty in saying how many doses of each vaccine their children had received thus far. Based on their reports about the number of doses of each vaccine the child had received, we classified each child as up to date or behind schedule in his or her vaccinations. For DTP, Polio, and HIB, the respondents tended to misreport that their children were not up to date; for all three of these vaccines, roughly a third of the reports mistakenly indicated that the child had not received all the recommended doses (see the "Net Bias" column in Table 1). Once again, the direction of the error was reversed for MMR, where respondents tended to report mistakenly that their children were up to date. The respondents also seemed to have difficulty reporting whether their children had ever received any doses of each vaccine (see Table 2).

None of the three experimental variables included in the first study had consistent effects on reporting accuracy. We included an item intended to identify the strategy respondents used in answering the immunization questions. The majority of respondents attempted to recall either specific visits (27%) or information about each vaccination on the vaccination card (39%). The major predictor of accuracy was knowledge about vaccinations. We asked respondents what disease or diseases each vaccine was intended to prevent and the number of recommended doses for each vaccine. Respondents who answered the knowledge questions correctly were more likely to answer the vaccination history questions correctly. If the chief barrier to accurate reporting is encoding the information correctly in the first place, respondents with more knowledge about the vaccines would appear to have an important advantage.

Taken together, the results of the two studies suggest that further efforts to improve recall (e.g., through enhancements to the calendar) are unlikely to yield much payoff. Instead, we need to develop methods for improving reports among respondents who may remember their visits to the pediatrician but who never really noted the specific vaccinations their children received during those visits.

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