INITIAL EXPERIMENTS WITH RFID TECHNOLOGY

Jay A. Mattlin, Michal Galin and Mark McLaren, Mediamark Research Inc.*

Two years ago, at the Prague Symposium, Mattlin and McDonald described RFID technology, provided some background information on the RFID industry, and discussed the implications of attempting to replace self-reports of readership with passive measurement of print audiences through RFID technology. This paper will review the earlier paper, describe MRI's subsequent experiments with RFID technology and the results of those experiments, and speculate on the implications of those experiments on the potential uses of RFID technology in the measurement of print audiences.

BACKGROUND 1: THE PROMISE OF RFID TECHNOLOGY

Hopes for measuring print passively have rested primarily on the shoulders of RFID technology. RFID, which stands for Radio Frequency Identification, refers broadly to a group of "technologies that use radio waves to automatically identify people or objects." (from "Frequently Asked Questions" in rfidjournal.com) RFID "tags" or transponders are like powerful electronic bar codes. They can carry much more information than bar codes, such as the serial number of an individual *item*. Unlike bar codes, some RFID tags can have new information added to them. And it is possible for an RFID scanner – which is called a tag "reader" -- to read an RFID tag without being very close to the RFID tag and without being in the tag's "line of sight."

An RFID tag consists primarily of a microchip and an antenna coiled around it. The microchip contains a unique identifying code. A tag reader sends and receives electromagnetic waves to the area around it. When a tag comes within the RFID tag reader's range, the tag's antenna receives those electromagnetic waves and then sends the chip's unique code back to the tag reader at a different frequency. The tag reader, also equipped with an antenna, receives the unique code and transmits it to a central server.

The most common kinds of tags resemble labels. These tags, which do not contain their own power source, are called "passive tags." Tags with batteries are called "active tags." Active tags have a longer range than passive tags -- up to 100 feet for some active tags, compared to a maximum of 15 feet for passive tags -- but their life span is dependent on the life of the battery, and their cost is considerably greater.

RFID tags are employed all over the world for a variety of purposes. The most familiar applications of RFID technology are automated toll collection and security systems for offices and buildings. The fastest-growing application of RFID technology is supply chain management, the tracking of goods as they move through a distribution pipeline. (Mattlin and McDonald 2005) A number of prominent companies have experimented with, developed, or employed RFID technology, including . . .

- Retailers such as Wal-Mart, Target, Best Buy, Albertson's, Tesco, Benetton, Metro AG, and CBD (the largest grocery chain in Brazil);
- Technology companies, such as IBM, Oracle, Sun, Phillips, and Texas Instruments;
- Credit cards companies, such as MasterCard and American Express;
- Consumer packaged goods companies, such as Gillette, Procter & Gamble, and Kimberley-Clark;
- And quick-service companies, such as Exxon-Mobil and McDonald's.

It has been envisioned that this technology could possibly give magazines and newspapers an electronic trail, so that their usage could be tracked passively in the same way as television, radio, and the Internet. Affixing tags to every magazine and giving portable RFID tag readers to a panel of people could, it has been speculated, put print on the same footing as these other media by enabling publishers and planners to obtain audience estimates for individual issues, possibly even individual ads; by providing estimates of time spent with an issue and the average number of times a reader is exposed to a particular ad; and by measuring the rate at which individual issues build their audiences over time. Passive measurement through RFID tagging would also eliminate a host of measurement issues that have bedeviled the publishing industry since the first Symposium -- reliance on respondents' memories, title confusion, problems in measuring magazines with irregular frequencies, and the model bias of recent reading for measuring average issue audiences. In short, if it were possible to replace self-reports in a survey with a panel whose exposure to print would be tracked by RFID tag readers and RFID tags in magazines and newspapers, the practice of print measurement would be revolutionized.

* The authors would like to acknowledge the assistance of all of MRI employees who participated in these experiments as subjects and Kerry Zarnitz, who administered most of the earlier tests

BACKGROUND 2: THE PERILS OF RFID TECHNOLOGY

The second part of the Prague Symposium paper outlined just how far away this vision was from becoming a plausible reality. There are five major categories of obstacles to bringing about this revolution:

1. **Economic factors**: Passive tags have come down in price, and it is now possible to purchase passive tags for five cents apiece in quantities of one million or more. (Meirs 2007) For smaller quantities, the minimum per unit price remains about 20 cents. Even at one nickel per magazine, placing a passive tag on every issue of a weekly with a print run of one million copies would cost $2.6 million per year (.05 * 52 weeks * 1,000,000 copies per week). The minimum cost of active tags is five dollars for an order of one million units or more.

2. **Political factors:** RFID technology continues to raise the hackles of privacy advocates, whose protests have derailed tests of the technology in stores in several countries. (Albrecht and McIntyre 2005)

3. **Technical factors**: Trying to measure reading with RFID tags poses several technical obstacles, including . . .

   - **How to identify a reading event**: Mere proximity to a magazine does not necessarily indicate that a person is reading that magazine;
   - **Interference**: Reading of a tag can be obscured by liquids, metal, the presence of other tags or other radio waves.
   - **Size of the tag reader**: The smaller the tag reader, the shorter its range. A portable tag reader would need to be sufficiently small to be carried easily but sufficiently large to detect a tag that may not be placed close to it.
   - **Accuracy of the technology itself**: Most tagging systems do not claim to be 100% accurate.

4. **Research issues:** Replacing survey questions posed to a sample with portable RFID-tag-reading devices given to a panel raises a host of research issues, such as:

   - **The need for publisher cooperation**: Every issue of every measured magazine would need to carry RFID tags. Without universal publisher participation, not all of the magazines covered by the research service could be measured.

   - **Respondent cooperation**: Our already-fragile response rates could suffer further erosion if respondents are required to carry a device with them everywhere they go. Moreover, maintaining panelists' participation is a daunting challenge, as our colleagues in radio and television measurement have long known.

   - **Panel management:** The field costs of managing and maintaining a panel are far greater than those of managing a static cross-sectional survey.

   - **Other data production costs**: The costs of incentives, data processing for a larger volume of data, and the RFID tag-reading devices would result in far greater costs than those of our current studies.

   - **Technical problems**: Equipment failures pose a serious problem for any kind of electronic measurement. For print, the damage from equipment failures is greater than for other media, because magazine and newspaper reading occur less frequently than radio listening or TV viewing.

   - **New sources of bias**: If there are places that respondents are reluctant to carry their portable RFID tag readers, reading occasions in those places would be under-reported.

   - **Need for larger samples**: If a panel study of print exposure aimed to measure readership of individual issues, the size of the sample would actually have to increase if consistent reliability standards are to be maintained, because readership of individual issues often falls below readership of the average issue.

5. **Philosophical issues:** Finally, a philosophical question hovers at the edge of any effort to shift from recall-based measurement to passive measurement of print. Those of us who work for publishers or whose research has focused primarily on magazines and newspapers tend to believe that engagement with these media is qualitatively different from engagement with television or radio. We like to think that readers forge stronger bonds with what they choose to read than they do with what they watch or listen to, that reading requires a more conscious cognitive interaction with the material. If this medium were to be measured in the same way as electronic media, then wouldn't this imply that the reading experience is no different than the experience of exposure to electronic media? Would passive measurement of print imply that consumers' interaction with print is as passive as their interaction with electronic media? This may be one unintended consequence of following the other media in the march to electronic measurement.

The 2005 paper concluded that, for all of the reasons enumerated above, the vision of migrating from a recall-based to an RFID technology-based system for measuring exposure to print was a distant vision, not readily realizable in the foreseeable future.

MRI'S APPROACH

This conclusion did not constitute a categorical rejection of RFID technology. Instead, it focused our attention, for the near term, on more limited applications of the technology. Specifically, we sought to explore whether the power of RFID technology could be harnessed to . . .

1. Obtain more precise measurement of quality-of-reading metrics, such as time spent with an issue and frequency of reading occasions; and

2. Measure levels of exposure to individual pages.

For both purposes, RFID technology would be used to enhance our readership survey rather than replace it. Learning whether it is possible for an RFID-based system to detect exposure to individual ads is particularly important in light of the direction in which television measurement has gone in the United States, where commercial ratings have just recently been offered.

These objectives allowed us to avoid or at least alleviate many of the obstacles enumerated above. Specifically, we would be using RFID tags in *samples* of particular issues of magazines, rather than in *every* printed issue of *every* magazine. By doing so, the system we sought to develop would . . .

- Cost much less than a full-scale replacement of the traditional print readership survey because tags would not need to be placed in every issue;
- Avoid some of the political repercussions because our objectives could be accomplished with a smaller sample and without tagging every issue;
- Require the participation of *interested* publishers – *not all* publishers;
- Not jeopardize the levels of cooperation in our audience measurement study;
- Not affect the complexity or size of the sample in the audience measurement study.

MRI contracted with TagSense, an engineering firm in Cambridge, Massachusetts that grew out of the MIT Media Lab, to develop RFID sensing solutions to meet our two key objectives. After some initial experiments, the approach we adopted was to try to develop an "intelligent" magazine by placing an active tag within it and a sensing element on individual pages that would track when those pages had been opened and when they had been closed. The opening and closing data would be monitored by an external tag reader. In order to extract these data, the magazine needed to be placed near the tag reader. The external tag reader would not be portable; it would either be plugged into a laptop computer or be built into a piece of computing hardware that would stand alone.

Putting an active tag, rather than a passive tag, in the magazine allowed us to . . .

- Increase the range of the tag reader;
- Endow the magazine with a memory so that the magazine itself, powered by the tag, could hold a historical record of what had been done to it, no matter where it was taken;
- Embed a clock into the tag so that it could record the time of day at which a magazine or page was opened and the time at which it was closed.

In our initial foray into this brave new world, our intent was to measure *each reading occasion* rather than try to measure *each reader*. We sought, at this first stage, to try to answer the primary question that concerned us initially -- the purely technical question of whether it was even possible to reliably detect the opening and closing of a magazine and of individual pages with an RFID-based system. By building an intelligent magazine, the system would not be reliant on the willingness and ability of research subjects to carry a device around with them everywhere they go.

EXPERIMENT #1: FIRST SET OF PROTOTYPES

In the initial set of prototypes developed by TagSense, an RFID "sensor card," with a battery-powered tag, was affixed to the back of the magazine. Sensing elements were placed on three designated pages to allow us to monitor exposure to three particular ads. When placed within 50 feet of a tag reader attached to a laptop (as shown in Appendix B, Illustration 1), a software interface would inform us whether the magazine was opened to each of these three marked pages. As can be seen in Illustrations 2 and 3 of Appendix B, all three of the indicators on the display screen were designed to flash "Closed" in red when the three designated pages were all closed. When the magazine was open to a particular marked ad, the indicator for that ad was designed to change color and flash "Open" in green. Information was transmitted from the tag in the magazine to the tag reader at one-second intervals.

TagSense provided us with the software, one tag reader, and eight magazines with the RFID equipment. The RFID tags in this first set of prototypes did not store the data that were registered by the tag reader and the software was not configured to record the times of each opening and closing. Therefore, our experiments consisted of noting simply when the software indicated changes in the state of each of the three designated pages, either from closed to open or from open to closed.

Shortly after we received each prototype, we first tested it ourselves to determine whether it worked as it was intended to. Some of the early prototypes had to be shipped back to TagSense for reprogramming or adjustments to the hardware. Once we had received a set of eight prototypes that functioned at a baseline acceptable level, we began a formal testing program with employees of MRI and their friends and family members to learn how well the system worked in a controlled setting. By design, the eight magazines varied in their size (ranging from 72 pages to 376 pages), thickness, and the way in which they were bound. Four were saddle-stitched, and four were perfect-bound.

We developed a set of formal protocols for each test so that they could be conducted in a standard fashion. The protocol was divided into five distinct phases:

Phase 1: First, participants were instructed to flip through every page of the magazine from front to back.
Phase 2: They were then instructed to flip through every page of the magazine from back to front.
Phase 3A: A series of 11 steps in which respondents were asked to turn to pages of interest around the first ad and, in two of these steps, to the first ad itself.
Phase 3B: A comparable series of steps around the second ad
Phase 3C: A comparable series of steps around the third ad.

At each step within Phases 3A through 3C, participants were asked to turn to a particular page and stay at that page for 10 seconds. (For a list of the steps, see Appendix A.) Color-coded tabs were affixed to each of the pages of the magazine that participants were instructed to turn to during these three phases. These tabs were intended to make it as easy as possible for the test participants to turn to the appropriate pages when directed to. In order to test the robustness of the system in different reading positions, participants were instructed to hold the magazine in one of three different positions throughout a test – either on a table, in their laps, or in their hands. In this latter position, participants were asked to proceed through the protocol with the magazine held in two hands, with one hand supporting the spine and the other hand turning pages. In addition, in order to assess whether a stiffer backing would improve the system's stability, half of the tests were conducted with a clear plastic cover around the magazine, and half were conducted without such a cover.

An MRI researcher administered each test and told the subject what to do at each step. Throughout the test, the administrator watched the RFID tag reader display screen and recorded instances in which each of the three marked pages registered a change from "closed" to "open," or vice versa, and when these changes occurred. Results for each step were coded as pass/fail. If one step depended on a previous step (such as a "close" event requiring the successful completion of the preceding "open" event) and if an unsuccessful independent event made assessing the dependent event impossible, then the dependent event was coded as "Not Applicable." The result of this coding framework was that the base sizes for "close" events were likely to be smaller than the base sizes for "open" events, because the bases for the former included only those cases that registered an "open" at the prior step.

A total of 75 tests were performed on this set of magazines with a total of 35 people. Twenty-three of them participated in more than one test. The greatest number of tests completed by any single individual was eight (conducted over multiple days), but most of the subjects completed one or two. Though participants were sometimes given the same magazine to test more than once, they were never assigned the same reading position for the same magazine more than once.[1]

Metrics

The performance of the system was evaluated according to seven metrics for each marked page (i.e., the three pages with the designated ads). Three of the metrics essentially captured whether the indicator for a given marked page registered an "open" when the magazine was open to that page, while four of them captured whether the indicator for that page registered as "closed" when the participant closed that page or was turning to other pages. Each metric was scaled to a score of 0 to 100. The metrics are:

1. *"Open" Metric:* Whether the marked page registered as open when the participant turned to that page while flipping through the magazine from front to back (in Phase 1)
2. *"Closed" Metric:* Whether the system registered a switch from open to close for that page when the participant turned *past* the page while flipping through the magazine from front to back (in Phase 1)
3. *"Open" Metric:* Whether the marked page registered as open when the participant turned to that page while flipping through the magazine from back to front (Phase 2)
4. *"Closed" Metric:* Whether the system registered a switch from open to close for that page when the participant turned *past* the page while flipping through the magazine from front to back (Phase 2)
5. *"Open" Metric:* The percentage of times (out of two) that the system registered an open for the marked page when the participant was told to turn specifically to that page and stay there for 10 seconds (in Phase 3)
6. *"Closed" Metric:* The percentage of times (out of two) that the system registered a switch from open to close for that page when the participant was told to turn *past* that page in Phase 3
7. *"Closed" Metric:* The percentage of steps in Phase 3 in which the system indicated that the marked page had *stayed* closed while the participant was turning to other non-marked pages of interest with color-coded tabs.

[1] There was mild evidence that the test subjects varied significantly in their outcomes (for 4 out of 21 metrics), but it is impossible to separate the effects of the test subject from the effects of the magazine and the magazine position.

It should be noted that the standards for the first and third criteria are fairly stringent. Subjects flipped through the magazines at their own pace, and a few of them stayed on one of the marked pages for no more than one second.[2] We were therefore testing the system's responsiveness in a very short time span. Also, if a participant turned to a marked ad and two pages flashed as "open" on the screen, it was counted as a failure (i.e., a zero), even if one of the flashing pages was the page to which the magazine had been opened. This coding rule was adopted because a magazine can't be turned to two pages at once, and so if two ads appeared to be open, it would have to be disregarded if the actual status of the page were not being independently observed.

Although we attempted to conduct the same number of tests for each combination of magazine and magazine position, in practice there were some combinations that were tested more often than others. We therefore weighted the data so that the number of tests in each combination would be equalized. Therefore, in the results shown below, all of the magazines and all of the magazine positions are weighted equally.

Finally, it should be noted that when we began this experiment, we conducted some tests of the prototypes on a metal table. RFID signals tend to get scrambled when metal interferes with them, and our experience showed that our system was not immune from this sort of interference. When it became apparent that the metal table tests were consistently failing, we stopped conducting them. The 12 metal table tests are therefore not included in the foregoing analysis.

Results for First Set of Prototypes

The table on the following page shows results from the remaining 63 tests. Overall, the system could be said to be accurate 84% of the time. This figure was derived by taking the average of the three "open" metric scores and the average of the four "closed" metric scores for each ad, averaging them together for a composite score for each ad, and then averaging the three composite scores together. While this outcome may have seemed encouraging, our encouragement was tempered by the fact that the system was far more astute at recognizing the closing of a page than the opening of a page: Ninety percent of the page closings were detected accurately, while the system successfully detected just 78% of the page openings. Thus, although these first prototypes did succeed in passively measuring page openings to some degree, they tended, on balance, to under-represent them.

The situation in which the system appeared to have the greatest difficulty was flipping through a magazine from the back cover to the front cover. While this may be less common than starting a magazine at the beginning, the configuration of the hardware did not seem well prepared to handle the back-to-front reading experience. On average, less than two-thirds (63%) of the marked pages registered as open at the appropriate times when the magazine was flipped from back to front. For the second ad, 58% of the back-to-front flips yielded an accurate "open" read.

In contrast, the prototypes behaved most accurately around Phases 3A, 3B and 3C when testing was directed at the actual locations of the marked pages and their surrounding pages (i.e., the pages before and after the marked pages). The average accuracy level in Phase 3 was 92%. When a participant was directed to turn to a marked page, the system was able to recognize the opening of that page an average of 88% of the time. This was particularly encouraging, because these phases were the ones that probably most closely mirror consumers' most common reading experiences – or at least, those that would be most valuable to advertisers.

Overall, the three marked pages performed similarly, with some variations in levels of accuracy. In general, the performance of the second marked page was the weakest, with an aggregate score of 82, compared to scores of 85 and 86 for Ads 1 and 3, respectively. When the magazine was flipped from front to back or back to front (Phases 1 and 2 of the testing), the measurement of Ad 1 tended to be the most accurate. The measurement of Ad 3 was the most accurate during Phase 3 the portion of the test when the magazine was opened to the marked page and the pages before and after it (shown in the row marked "Turning to and from the ad" in the table below). The three ads were measured with similar levels of accuracy when participants went through the steps of the test that moved around one of the marked pages but not specifically on one of the marked pages (row marked "Turning to other pages" in Table 1).

[2] We did not record the time spent on the marked page in the first experiment, but in Experiment #2, less than 10% of the openings of marked pages in Phases 1 and 2 lasted just one second.

SUMMARY OF EXPERIMENT #1 RESULTS

All Magazines	Open Accuracy	Close Accuracy	Overall Accuracy
MARKED PAGE WITH AD 1			
Flip Front to Back[1]	81	99	90
Flip Back to Front[2]	68	84	76
Turning to and from the marked page[3]	83	97	90
Turning to other pages[4]	NA	92	92
Average	77	93	85
MARKED PAGE WITH AD 2			
Flip Front to Back[1]	83	90	86
Flip Back to Front[2]	58	71	64
Turning to and from the marked page[3]	88	97	92
Turning to other pages[4]	NA	91	91
Average	76	87	82
MARKED PAGE WITH AD 3			
Flip Front to Back[1]	87	92	89
Flip Back to Front[2]	62	81	72
Turning to and from the marked page[3]	93	97	95
Turning to other pages[4]	NA	93	93
Average	80	91	86
AVERAGE ACROSS 3 MARKED PAGES			
Flip Front to Back[1]	83	94	89
Flip Back to Front[2]	63	78	70
Turning to and from the marked page[3]	88	97	92
Turning to other pages[4]	NA	92	92
Average	78	90	84

Base: 63 tests with 8 prototypes
1. Averages for Metrics 1 and 2
2. Averages for Metrics 3 and 4
3. Averages for Metrics 5 and 6
4. Average for Metric 7
Overall accuracy=average of open accuracy and close accuracy

Breakdowns of the system's performance by magazine characteristics, magazine position, and the presence of a plastic cover are shown in Table 1. As can be seen in this table, . . .

- Avoid some of the political repercussions because our objectives could be accomplished with a smaller sample and The binding of the magazine does appear to impact the accuracy of the system. Across all the ads and in terms of both "open" and "close" accuracy, the saddle-stitched prototypes outperformed the perfect bound prototypes. In all instances except for "close accuracy" when flipping from front to back, the accuracy levels of the saddle-stitched prototypes were at least 10 percentage points higher than those of the perfect bound prototypes.[3]

- The length of the magazine also appears to affect the accuracy of the device. In general, the shorter magazine prototypes performed more accurately than the longer magazine prototypes, especially with respect to measuring the closing of a marked page[4]. ("Longer" is defined here as an issue with 200 or more pages. This difference in accuracy would still have been observed if the definition of "longer" had been broadened to include magazines of 180 pages or longer.)

- There are some differences in levels of accuracy related to the position of the magazine, but these differences are generally not as marked as those due to binding and length. The system tended to have greater difficulty in detecting a page opening when the magazine was placed on the participant's lap than in their hands or on a table. This was

[3] This advantage of the saddle-stitched magazines was particularly evident when flipping the magazine from back to front, where the differences in accuracy were statistically significant for four out of six metrics. (i.e., the opening and closing of three marked pages, 2 x 3.)
[4] For three out of the six metrics for detecting activity when the magazine is flipped back to front, this difference in detecting a page closing was statistically significant.

particularly true for the third marked page, with a gap of over 20 points between the "In hands" and "In lap" positions in their "open" accuracy scores for that page. (This difference was statistically significant for the forward and backward-flipping steps, after controlling for the differences between magazines.)

- The clear plastic cover did seem to raise the likelihood that the opening of the first marked page would be detected. It also appeared to increase the likelihood that the closing of the second marked page would be detected.

One of the ads included in this first set of prototypes was a so-called "high impact" ad –a sort of pop-up with thicker paper stock. The opening to this ad was detected at the same rate as the average first ad among the eight magazines, with an average accuracy score of 77. However, its closing accuracy score was far below the norm. The closing of this page was accurately registered 68% of the time.

Conclusions About the First Prototypes

On the whole, the results we obtained with these first prototypes seemed to be promising. This experiment demonstrated that an RFID-based system has the potential to fulfill the second of the two objectives outlined earlier. Nonetheless, the system's ability to identify openings of pages, particularly when the reader is flipping from the back of the magazine to the beginning, was not sufficiently robust to be acceptable.

Other observations:

- Among the three reading positions we tested, none of them presented an insurmountable problem for passive measurement.
- The thicker magazines pose a challenge to the system, because the marked pages are closer to the measurement mechanism in the thinner magazines. This proximity allows for a stronger reception of the radio frequency signal, which facilitates the calibration of the signal as indicative of an "open" or "closed" state. It may be that there is an upper limit to the number of pages between the sensing device and the marked page. If the active RFID tag is placed in the back of an extremely thick magazine, it is difficult, at least currently, to detect the movement of a page at the beginning of the magazine.
- The stronger performance of the saddle-stitched magazines may be attributable to the way that the pages of a magazine fall when a perfect-bound magazine is opened. They tend to curl up more, rather than lying flat on the back cover. The RFID sensor, embedded in the back cover, may have more trouble assessing the status of the pages of a perfect-bound magazine because its pages may be less likely to fall flat on top of it.
- The weaker ability to detect reading activity when flipping from the back of the magazine to the beginning may also be related to the position of the RFID sensor in the back of the magazine and the way the pages fall in relation to it.

We hypothesized, with support from TagSense, that a plastic cover could help alleviate some of the problems with the natural tendency of magazine pages to curl in certain positions. Since the plastic cover appeared to improve the prototypes' ability to detect the opening of the first marked page, it was decided that all of the next set of prototypes would include a clear protective plastic cover. It was thought that the plastic cover would help stabilize the magazine's covers and pages.

EXPERIMENT #2: SECOND SET OF PROTOTYPES

In the second set of eight prototypes, the sensor card and battery were tucked inside a flap of a clear plastic cover into which the back cover of the magazine was inserted. This made the hardware less obtrusive.

This set of prototypes differed from the first set in several ways. In addition to the plastic cover, these prototypes were designed to measure the opening and closing of the *magazine*, as well as pages within it. Therefore, a sensing element was inserted into the front flap of the plastic cover. For technical reasons, because we were attempting to detect opening and closing of the magazine, the number of pages we could detect within the magazine was reduced from three to two.

The other major differences between this set of prototypes and the first set were upgrades in the hardware and software: The tags with these prototypes were equipped with a memory that logged all of the information they registered on the openings and closings. This was a key part of our original intent in designing an intelligent magazine, one that would be able to record and store its history. This capability also facilitated our analysis by allowing us to review the records of our tests after they had been conducted. In addition, for this set of prototypes, the software interface included the *time* of each opening and closing instead of a simple open/close indicator. A screen shot of the new display can be seen in Appendix B, Illustration 4. This new feature allowed us to move closer to our first objective – the measurement of duration of the reading experience.

The testing protocols were modified to accommodate these new features. The first two phases of flipping through the magazine front to back and back to front were timed by the test facilitator with a stopwatch so that the actual times that the magazine and the marked pages were open could be recorded. These times could be compared to the times logged by the system. In the third Phase, in which participants were asked to turn to particular pages and remain there for 10 seconds, the instructions for these tasks were prerecorded so that the times at each step could be standardized to 10-second intervals.

For this test, we replaced one of the magazine positions with two others and added a fifth position. The new positions were:

- **In lap, legs not crossed**
- **In lap, legs crossed**
- **Held naturally**: Subjects were asked to proceed through the protocol with the magazine held in the manner most natural for him or her.

At our request, for the second experiment, Tagsense produced two different kinds of prototypes. Four of the prototypes were wired to provide readings on the opening and closing of two marked pages, plus the opening and closing of the magazine. In these prototypes as in the set for the first experiment, the marked pages contained sensing elements. The other four prototypes did not contain any sensing elements in the pages of the magazine and were designed solely to produce signals to indicate whether the magazine itself was open or closed. The former prototypes will be referred to hereafter as the "dual-purpose" prototypes, while the prototypes which monitor only the activity for the entire magazine will be referred to as "single-purpose" prototypes.

The series of steps in the protocol for the four dual-purpose prototypes were the same as the series of steps in the protocol for the first experiment. For the single-purpose prototypes, the steps in the protocol were altered slightly. The first two phases remained the same. In the third phase, subjects were asked to open the magazine to a particular page, stay on that page for ten seconds, and then close the magazine. This sequence was repeated for five different pages throughout the magazine. (See Appendix A for details.) For all of the prototypes in the second experiment, colored tabs were attached to each page to which subjects were asked to turn, as was done in the first experiment.

Subjects for these tests were recruited in the same manner as for the first experiment. Altogether, we conducted 90 tests with 36 individuals. Two-thirds of these individuals participated in two or more tests, with the maximum for any one person being six. (Two of the subjects participated in six tests.) Again, no individual was assigned the same combination of prototype and reading position more than once. Three of the tests were dropped from the analysis because they were done with the magazines on metal tables, which was clearly not an environment in which this system could function properly. So, the foregoing analysis was conducted with 42 tests of the dual-purpose prototypes and 45 tests of the single-purpose prototypes.

Metrics

The seven metrics used to evaluate the first experiment were also used to evaluate the results of the testing for dual-purpose prototypes in the second experiment. For the single-purpose prototypes, there were six open-close metrics, rather than seven, because the protocol for these prototypes did not include the steps that were used in the calculation of the seventh metric.

In addition, we collected and coded the duration of each instance in which a page or the magazine registered an opening. These data were used to calculate three additional metrics:

1. **Amount of open time under-reported**: Every time that the system correctly registered that a page had been opened, we calculated the number of seconds that it registered as open. From this, we derived the number of seconds that were under-reported in each of the steps in Phase 3 in which subjects were asked to keep a marked page open for 10 seconds. We allowed for a one-second margin of error within the 10-second span. So, the amount of open time that was unreported was set at zero if the duration for an opening at an individual marked page was recorded as nine seconds or more. For each case of an opening duration that fell below nine seconds, the number of unreported seconds was calculated as the difference between nine and the duration logged by the system.

   Among the dual-purpose prototypes, a similar measure was calculated for the amount of unreported open time for the magazine as a whole, based on the indicator in the interface for the magazine as a whole. For the four single-purpose prototypes, the system should have registered as open for a total of one minute and forty seconds across all of the steps of Phase 3. We therefore calculated the difference between the total time that the magazine *registered* as open and 100 seconds. If this total was less than 100, it was subtracted from 99 to serve as an indicator of how close the system's *recorded* magazine-open times were to the actual magazine-open times across many openings and closings.

2. **Amount of open time over-reported:** Each time in Phase 3 that an open marked page registered as "open" for *more* than 11 seconds, we calculated the excess of that time over 11 seconds (again, allowing for a one-second margin of error over the 10 seconds that the page was supposed to be open). This represents the amount of time beyond the allotted 10 seconds that the system continued to record that a marked page was still open. A similar procedure was used for calculating this metric for the amount of over-reported time for the magazine as a whole for the dual-purpose

prototypes. For the single-purpose prototypes, this measure was calculated based on the total of 100 seconds that the magazine was supposed to be open during Phase 3.

3. **Percent of time in incorrect state**: In Phases 1 and 2, the amount of time that subjects spent flipping through the magazine forward and backward varied across the subjects and across the magazines. We calculated the absolute value of the difference between the total of amount of time that the magazine registered as open and the total amount of time that it was actually open during each of these phases, according to the administrator's stopwatch. We then divided this difference by the amount of time that the magazine was actually open. These figures therefore represent the percentage of seconds that the magazine's status was incorrectly reported during Phase 1 and Phase 2.

Results for Second Set of Prototypes

In general, the changes in the system . . .

- Produced valuable additional data on the durations of the page exposures and magazine exposures which proved to be highly accurate;
- Produced extremely robust measures of magazine openings and closings;
- Did not improve on the accuracy of the measurement of page openings and closings. Indeed, there was some evidence that encasing the magazines in plastic covers may have hindered the measurement of pages in certain magazines in certain situations.

SUMMARY OF EXPERIMENT #2 RESULTS FOR 2 MARKED PAGES

All Magazines	Open Accuracy	Close Accuracy	Overall Accuracy
Marked page with Ad 1			
Flip Front to Back	83	91	87
Flip Back to Front	49	64	57
Turning to and from the marked page	83	91	87
Turning to other pages	NA	94	94
Average	72	85	78
Marked page with Ad 2			
Flip Front to Back	76	97	86
Flip Back to Front	53	78	65
Turning to and from the marked page	75	90	83
Turning to other pages	NA	95	95
Average	68	90	79
Average of two marked pages			
Flip Front to Back	79	94	87
Flip Back to Front	51	71	61
Turning to and from the marked page	79	90	85
Turning to other pages	NA	95	95
Average	70	88	79

Base: 42 tests with four magazine prototypes

Page Opening and Closing

As can be seen in the table above, this modified system could be said to be accurate 79% of the time, slightly lower than the comparable score for the first set of prototypes (83%, not including the third marked page). The system's record in identifying openings of the first marked page, except in the back-to-front mode, was comparable to its record in the first experiment. In all other respects – measuring back-to-front mode, page closings, and the second ad -- the second system's accuracy scores were lower.

This reduced performance may, we believe, be attributable to the effect of the hard back plastic cover, weighed down slightly by the RFID equipment (which had been attached to the magazine in the first experiment) on the way that the pages at the back of the magazine fall in relation to it. In the first experiment, we had simply inserted the magazine into a loose plastic cover. In this second experiment, the magazines were bound into the plastic cover at the spine. This tighter binding may have detracted from some of the benefits of the plastic cover that we saw in the first experiment.[5] It is possible that these problems could be overcome in the future development of the system if the RFID equipment could be made lighter or if the plastic cover could be attached in a less intrusive manner.

As was found with the first set of prototypes, the system more successfully picked up page closings than page openings. Overall, the two marked pages in the second set of prototypes achieved about the same level of accuracy. However, the system was slightly more accurate in detecting the opening to Ad 1 and a bit more accurate in detecting the closing of Ad 2.
Breakdowns of this system's performance by the characteristics of the magazine (binding, length) and the reader's position are shown in Table 2.

- Again, the binding of the magazine does appear to impact the accuracy of the system. However, in the case of this second system, the perfect bound magazines outperformed the saddle-stitched magazines. This second system's overall accuracy rates with perfect-bound magazines actually exceeded the first system's accuracy rates with both saddled-stitched and perfect-bound magazines. The difference between the performance levels of the two systems is largely rooted in the system's difficulty in detecting the openings of marked pages in the two saddled-stitched magazines. For five out of the six "open" metrics (three for the first ad, three for the second ad), the differences between the saddled-stitched and perfect-bound magazines' accuracy levels were statistically significant.

- Only one of the magazines was over 200 pages long and so was coded as "longer." As was the case with the first experiment, the system measured this magazine less accurately than the shorter magazines for page "opens." (This would still have been the case if the 184-page magazine had been classified as "longer.") However, the opposite was true of "close" accuracy for the first marked page.

- There were some differences in levels of accuracy related to the position of the magazine, but these differences were generally not as marked as those due to binding and length. Nonetheless, the system's ability to recognize page openings was not particularly strong among participants who held the magazine in their hands and in the way that was most natural for them (62 and 67, respectively).

- Reading the magazine on one's lap, which was the reading position that the cover had originally been intended to help us measure more effectively, was the only position for which the plastic cover-bound system worked as well as the system in the first experiment. It seemed to make little difference whether respondents cross or didn't cross their legs when they read the magazines in their laps. The system was somewhat more likely to recognize the opening of the second marked page when the subject's legs were not crossed, but otherwise, their accuracy scores were close.

When the system did correctly report the opening of a page, the time that it reported that the magazine was open to the page was usually quite close to the actual duration of the page opening– rarely more than a couple of seconds over or under. Both the amount of unreported time and the amount of over-reported time were very small. In Phase 3, when the magazine was supposed to be open to each marked page for 10 seconds, the average amount of time over 11 seconds that the system recorded that one of the marked pages was open was 1.1 seconds (with reports under 11 seconds set at 0). The average amount of time under nine seconds that the system reported an opening of one of the two marked pages in Phase 3 was just 0.7 seconds. Thus, there is a slightly greater tendency for the system to report that an opening lasted longer than it actually did than for the system to report an opening time below the actual opening time, but this exaggeration of opening time is very slight.

The conditions under which the greatest inflation of open time occurred were for the first ad with perfect-bound magazines (average of 2.8 seconds) and when the magazine was being read on a table (average of 4.2 seconds). The situation in which the amount of time was most severely under-reported was for the second marked page when the magazine was held in the respondent's hands (average of 2.2 seconds). Otherwise, the recorded amounts of time spent on marked pages were very accurate.

Magazine Opening and Closing

As can be seen below, the RFID mechanism to detect magazine opening and closing worked extremely well. Among the four dual-purpose prototypes, the new system detected the opening of the magazine when the participant flipped from front to back and from back to front *in every single test*. At the two points in Phase 3 of the protocol for the dual-purpose prototypes when participants were told to open the magazine, the system accurately recorded a magazine opening 94% of the time. The rates at which the system accurately measured magazine closings were slightly lower than for magazine openings for the dual-purpose prototypes, but they were still consistently at 90% or higher.

In fact the system worked perfectly in every single test of three of the four dual-purpose prototypes. All of the scores in Table 3 which are not 100 come from just one of the prototypes – the thick saddle-stitched magazine. This prototype's ability to detect

[5] It is also possible that the timing information provided by the new software inadvertently led our coding of "passes" to become more stringent. This could also have occurred because of a change in staffing between Experiment #1 and Experiment #2: The testing administration of Experiment #2 was carried out by a different staff member than most of the administration of Experiment #1.

the magazine closings when flipping from back to front was relatively weak (score of 60). It was a bit more effective in detecting openings and closings during the steps of Phase 3 in which the magazine was opened and, later on, closed. This prototype's "close" accuracy score for these steps stood at 72.

The accuracy rates for the single-purpose prototypes were also extremely high, consistently over 90% overall. One of them, a moderate-length saddled-stitched magazine, had a perfect record on every test. Overall, the average performance of the four single-purpose prototypes was about the same as that of the dual-purpose prototypes (with overall scores of 95 for the former vs. 96 for the latter).

SUMMARY OF EXPERIMENT #2 RESULTS FOR OPENING AND CLOSING OF MAGAZINES

	Open Accuracy	Close Accuracy	Overall Accuracy
ALL DUAL-PURPOSE MAGAZINE PROTOTYPES			
Flip Front to Back	100	98	99
Flip Back to Front	100	90	95
Steps where Magazine is Opened or Closed	94	93	94
Average of 3 Tasks Above	98	93	96
ALL SINGLE-PURPOSE MAGAZINE PROTOTYPES			
Flip Front to Back	95	97	96
Flip Back to Front	90	95	92
Steps where Magazine is Opened or Closed	97	96	97
Average of 3 Tasks Above	94	96	95

Base: 42 tests with 4 dual-purpose prototypes, 45 tests with single-purpose prototypes

The magazine positions in which the single-purpose prototype were the most reliable in detecting magazine openings were the ones in which the participants placed the magazine in their laps. (See Table 4.) When the subjects went through the single-purpose prototypes in their laps, the system succeeded in identifying every magazine opening in every phase. When subjects' legs were crossed, the system almost always detected magazine closings as well. When the readers' legs were not crossed, the system still managed to detect 89% of the closings. Placing the magazine flat on a table was the best position for detecting the closing of a single-purpose prototype, with a 100% closing accuracy score in all phases.

The system was generally quite robust in detecting magazine openings when the single-purpose prototypes were held in the subjects' hands or when they were held as the subjects would have naturally held them. When subjects held the magazines in their hands, the prototypes were always able to detect the magazines' opening when the subjects were flipping through them from front to back. And when subjects held the magazines naturally and were asked to open the magazine to a specific page (in Phase 3), the single-purpose prototypes recognized the magazine opening 97% of the time.

In addition, when the system correctly identified a magazine-opening occasion, the RFID sensing equipment recorded the amount of time that the magazine was open with great precision. The mean absolute difference between the time logged by the RFID sensor and the actual time recorded by the test administrator and his stop watch (not including cases where no opening was registered at all) when the subjects were flipping through the magazine from front to back was 1.5% of the actual time for the dual-purpose prototypes and 1.8% of the actual time for the single-purpose prototypes. In other words, for every 100 seconds that the participants spent flipping through the magazine from front to back, the RFID logging mechanism, when it spotted a magazine opening, would get the total time right within an average of two seconds. When leafing through a magazine from back to front, the system's timing was almost as precise – within 1.8% on average for the dual-purpose prototypes and within 2.3% for the single-purpose prototypes.

In the Phase 3 steps in which the subjects were asked to keep the magazine at a particular page for 10 seconds, the durations recorded were mostly within one second of the allotted 10 seconds. The average amount of under-reported time (counting all the durations between nine and 11 seconds as zeros) was about half of a second, while the average amount of over-reported time was less than a tenth of a second. Thus, when the system accurately identified a magazine opening, it also tended to record the timing of that opening accurately.

IMPLICATIONS OF THESE RFID EXPERIMENTS FOR PASSIVE MEASUREMENT OF PRINT

These experiments have provided evidence that RFID technology can be used to measure exposure to magazines in certain situations. When embedded in a plastic magazine cover in a laboratory setting, the technology appears to work well in identifying occasions when a magazine has been opened and when it has been closed and how long it has been opened each time. It works well in a variety of magazine-reading positions, though our tests suggested that the system may have worked better in some reading positions than others. And the system proved capable of robust measurement of the opening and closing of both saddled-stitched and perfect-bound magazines.

The tests also indicate that while RFID technology is capable of gauging the openings and closings of individual pages, it is not yet ready to be fully deployed for this purpose and could be used now only to a limited degree. Without plastic covers around the magazine, the technology we tested would not be considered sufficiently robust to warrant confidence in its reliability for measuring perfect-bound magazines. With plastic covers, the same would be true of saddle-stitched magazines, based on the page-opening detection rates for the two saddle-stitched dual-purpose prototypes. With plastic covers, it would also not be expected that the current system would be sufficiently capable of detecting the opening of a page of interest in certain common reading positions, such as in the readers' hands and in a "natural" reading position. Additional technical development and refinement are necessary to raise the page-opening detection rates of all magazines in all positions to the average page detection rates for the first ad in the perfect-bound dual-purpose prototypes.

Ultimately, the results of these experiments confirmed our suspicion that the measurement of magazine audiences through RFID technology on a large scale is still a long way from becoming technically and financially feasible. Powerful as we discovered this technology to be, the system we developed could not be used for a broader purpose without considerable additional technical refinements. Any such system would have to contend with a number of limitations:

1. **Cost:** The hardware embedded in each prototype – the active tag, the internal clock, the memory, the battery, and other components – costs more than $20 per unit. Since this is several times the newsstand price of any major magazine in the U.S. today, installing such hardware in every copy of a magazine would be financially inconceivable.

2. **Metal**: Our system performed so poorly on metal tables that we abandoned the testing of them in this environment. As noted earlier, metal interferes with RFID sensing capabilities. This is a scientific limitation requiring extensive additional technical research for our RFID system, or any RFID-based system, to overcome.

3. **High-impact ads**: High-impact ads, such as pop-ups, music-playing inserts, and fold-outs, have become increasingly common in the United States as a means of "breaking through the clutter" of traditional print advertising. For the one ad we tested of this sort, we found that the system's response was erratic. This experience, bolstered by TagSense's reservations, convinced us that it would be difficult to use this technology to measure expensive pop-up or fold-out ads.

4. **Number of ads:** Our current system can only accommodate three marked pages or two marked pages, plus the magazine itself. It is possible that the technology could be refined to expand to larger numbers of ads in the future, but there may be a practical limit to the number that can be tracked in any one magazine.

5. **Magazine size:** The RFID tag and the surrounding hardware would not, at this point, fit in digest-sized magazines.

6. **Bending the magazine:** There was one common reading position we didn't test: Folding over the section of the magazine preceding the page one is reading so that only one page is showing and the back cover touches the front cover. The reason we didn't attempt testing such a position is that it was explained to us that it would pose problems for our technology. While it is possible that these problems could be overcome, it is difficult to design a system that works equally well for a medium in which the covers can reverse positions.

7. **Magazine length:** The system simply didn't work as well at this point in detecting the openings and closings of longer magazines or the pages within them.

8. **Non-traditional reading – back to front**: Throughout our testing, the technology proved less capable of identifying opening and closing events when the magazine was being read from the end to the beginning than in the traditional, more common, front-to-back mode.

9. **Bias towards under-reporting of incidence:** In most cases, our system's performance was stronger in recognizing the end of an exposure to a marked page – turning past a marked page -- than opening to a marked page. In the aggregate, this tendency would yield a net under-reporting of page exposures. (This tendency would be counterbalanced to a small degree by the tendency of the system to very slightly over-represent the amount of time that a page is open.)

10. **Use of plastic cover:** The technology we developed for identifying the opening and closing of a magazine employs plastic covers. While it might be possible to implement a similar solution without plastic covers, our current design could not be implemented on a large scale on newsstands or among subscribers.

11. **Flexibility of the material:** It proved to be more difficult to obtain valid measurements of individual pages than of the magazine itself. The chief impediment to measuring magazine page exposure passively was probably the flexibility and lightness of the material from which this medium is built – paper. RFID tags are typically used on hard surfaces – thick security cards, plastic boxes attached to windshields, labels that are affixed to cases of goods. The fluidity of the pages of a magazine renders them a constantly shifting target. (For newspapers, this is an even more serious problem.)

    We were certainly aware of this potential obstacle when we began this project. Our experiment revealed that we were not completely able to overcome it. It may take a while for the technology to be fully adapted to this more flexible material.

It is important to note that these experiments were done with prototypes that were produced by hand. While prototypes can help in determining the viability of this technology and in identifying problems with it, the fact that prototypes are subject to the imprecision and variability of human hands may have produced variability in the performance of the equipment that would be eliminated if the equipment had been manufactured in an industrial process. It is possible that some of the problems we experienced -- such as the flexibility of paper, the lower success rate for individual pages, identifying back-to-front reading, the occasional lag between registered page turning and actual page turning -- could be resolved if the RFID sensing material were produced by a machine, in a precise, mechanical fashion. If the production of the RFID sensing equipment were standardized, it is possible that all of the magazines would perform as well as the best prototypes.

One key benefit of this system, which we did not formally test, was that imbuing the magazine with the power to track its own use enables us to measure exposure to that magazine use no matter where that exposure occurs. We witnessed this power in an informal way when one of us took a tagged magazine out of the room in which the testing was taking place and opened the magazine. The microchip in the active RFID tag continued to store data on the times at which the tag detected an opening or closing of a marked page or of the magazine itself. When the magazine was returned to the room, the tag reader extracted the data log from the tag and displayed the times at which the magazine had been opened out of the room.

In spite of the issues enumerated above, these experiments suggest to us that RFID technology could be adapted for the first objective we had envisioned for it. If publishers or advertisers are interested in determining times spent with magazines in public places, then it would be possible to estimate those times by deploying RFID-enabled plastic covers in a sample of public places. Because the exposure data are stored within the RFID tag, the system would record magazine openings and closings and the durations of those openings even if visitors to the waiting room take the magazine with them to another room (as long as they return it to the central waiting area later on.) Since the plastic covers are re-usable, the costs would be considerably lower than the cost of inserting active RFID sensors in a sample of magazines themselves.

Tracking the number of pick-ups and the amount of time spent with magazines in public places is the application we regard as the most feasible short-term application of RFID technology for measuring exposure to print. In the long term, it may be possible to extend this technology to the measurement of print in all settings. One magazine technology expert predicts that in five years, the cost of an active tag may fall to one dollar. (Meirs 2007) In those five years, it is also possible that advances in RFID technology may make them more adaptable to flexible surfaces. Miniaturization technology may expand the number of pages that can be tracked or may minimize the obtrusiveness of the sensing equipment.

So, the point at which it is technologically and economically possible to passively measure exposure to all magazines may arrive while most of us are still working in this field. It may even happen while magazines are still being printed and read on paper! Then, assuming we are philosophically comfortable with the notion of passive measurement of what we regard as an active medium, the only problems we will have to solve are the research problems enumerated at the last Symposium and at the beginning of this paper. And, as our colleagues in electronic media have discovered, these problems – gaining universal publisher cooperation, the cost of building a panel, expanding the sample to measure every page and every issue reliably, maintaining respondent cooperation – may turn out to be just as difficult to solve as the technical problems.

References

"Frequently Asked Questions," RFIDjournal.com.

Mattlin, J. A. and McDonald, S. C. (2005) "Passive Measurement of Print: The Promise and the Perils of RFID Technology." Worldwide Readership Research Symposium, Prague.

Meirs, P. (2007) "Making Sense of Sensing: Technologies for Magazine Measurement." MPA Measurement Meeting.

TABLE 1: EXPERIMENT #1 RESULTS BY MAGAZINE CHARACTERISTICS AND MAGAZINE POSITION

	OPEN ACCURACY	CLOSE ACCURACY	OVERALL ACCURACY
All Magazines N=63			
Ad 1	77	93	85
Ad 2	76	87	82
Ad 3	80	91	86
Average ad	78	90	84
Saddle-stitched N=35			
Ad 1	84	96	90
Ad 2	86	92	89
Ad 3	85	97	91
Average ad	85	95	90
Perfect bound N=28			
Ad 1	71	89	80
Ad 2	66	78	72
Ad 3	75	78	76
Average ad	71	81	76
Longer N=18			
Ad 1	71	86	78
Ad 2	70	76	73
Ad 3	75	77	76
Average ad	72	79	76
Shorter N=45			
Ad 1	81	97	89
Ad 2	80	91	85
Ad 3	85	97	91
Average ad	82	95	88
On table N=21			
Ad 1	84	95	90
Ad 2	79	77	78
Ad 3	77	90	83
Average ad	80	87	84
In lap N=26			
Ad 1	71	91	81
Ad 2	76	87	81
Ad 3	71	94	82
Average ad	72	91	81
In hands N=16			
Ad 1	76	93	85
Ad 2	73	98	86
Ad 3	95	90	93
Average ad	81	94	88
Without Plastic Cover N=32			
Ad 1	70	93	82
Ad 2	79	80	79
Ad 3	80	90	85
Average ad	76	88	82
With Plastic Cover N=31			
Ad 1	84	94	89
Ad 2	74	94	84
Ad 3	81	91	86
Average ad	80	93	86

Data for "Open Accuracy" are averages of three "Open" Metrics (Metrics 1, 3, and 5). Data for "Closed Accuracy are averages of four "Closed" Metrics (Metrics 2, 4, 6, and 7). The data for "Overall Accuracy" are averages of the "Open Accuracy" and "Close Accuracy" figures.

TABLE 2:

EXPERIMENT #2 RESULTS ON DETECTION OF TWO MARKED PAGES, BY MAGAZINE CHARACTERISTICS AND MAGAZINE POSITION

	Open Accuracy	Close Accuracy	Overall Accuracy		Average under-reported time (in seconds)	Average over-reported time (in seconds)
All Magazines N=42						
Ad 1	72	85	78		1.7	0.4
Ad 2	68	90	79		0.6	1.1
Average ad	70	88	79		1.1	0.8
Saddle-stitched N=21						
Ad 1	49	98	74		0.1	0.8
Ad 2	58	90	74		0.2	1.1
Average ad	54	94	74		0.2	1.0
Perfect bound N=21						
Ad 1	92	80	86		2.8	0.1
Ad 2	77	90	84		0.9	1.1
Average ad	84	85	85		1.9	0.6
Longer N=12						
Ad 1	66	98	82		0.2	0.7
Ad 2	56	84	70		0.3	0.5
Average ad	61	91	76		0.2	0.6
Shorter N=30						
Ad 1	73	83	78		2.2	0.4
Ad 2	72	91	82		0.7	1.3
Average ad	73	87	80		1.5	0.8
On table N=9						
Ad 1	78	82	80		4.2	0.0
Ad 2	68	98	83		0.1	1.3
Average ad	73	90	82		2.2	0.6
In lap: legs uncrossed N=8						
Ad 1	75	86	81		0.2	0.6
Ad 2	65	89	77		1.0	0.5
Average ad	70	88	79		0.6	0.5
In lap: legs crossed N=8						
Ad 1	76	89	83		3.0	0.7
Ad 2	76	87	82		0.9	1.4
Average ad	76	88	82		1.9	1.0
In lap (overall) N=16						
Ad 1	76	88	82		1.6	0.7
Ad 2	71	88	80		0.9	1.0
Average ad	73	88	81		1.3	0.8
In hands N=9						
Ad 1	66	78	72		1.0	0.2
Ad 2	58	85	71		0.3	2.2
Average ad	62	81	72		0.7	1.2
Held Naturally N=8						
Ad 1	63	87	75		0	0.7
Ad 2	71	93	82		0.9	0.1
Average ad	67	90	78		0.4	0.4

Data for "Open Accuracy" are averages of three "Open" Metrics (Metrics 1, 3, and 5). Data for "Closed Accuracy are averages of four "Closed" Metrics (Metrics 2, 4, 6, and 7). The data for "Overall Accuracy" are averages of the "Open Accuracy" and "Close Accuracy" figures.

TABLE 3

RESULTS OF EXPERIMENT #2 FOR OPENING AND CLOSING OF MAGAZINES AMONG THE DUAL-PURPOSE PROTOTYPES

	Open Score	Close Score	Overall Score		Avg under-reported open time (in secs)	Avg over-reported open time (in secs)	Avg Time (as pct) in Incorrect State
All Magazines N=42							
Flip Front to Back	100	98	99				1.5
Flip Back to Front	100	90	95				1.8
Steps where Magazine is Opened or Closed	94	93	94		1.4	0.1	
Average of 3 Tasks Above	98	93	96				
Saddle-stitched N=21							
Flip Front to Back	100	95	97				1.8
Flip Back to Front	100	79	89				2
Steps where Magazine is Opened or Closed	88	85	86		2.4	0	
Average of 3 Tasks Above	96	86	91				
Perfect bound N=21							
Flip Front to Back	100	100	100				1.3
Flip Back to Front	100	100	100				1.6
Steps where Magazine is Opened or Closed	100	100	100		0.5	0.2	
Average of 3 Tasks Above	100	100	100				
Longer N=12							
Flip Front to Back	100	90	95				1.4
Flip Back to Front	100	60	80				2.5
Steps where Magazine is Opened or Closed	77	72	74		4.8	0	
Average of 3 Tasks Above	92	74	83				
Shorter N=30							
Flip Front to Back	100	100	100				1.6
Flip Back to Front	100	100	100				1.7
Steps where Magazine is Opened or Closed	100	100	100		0.5	0.1	
Average of 3 Tasks Above	100	100	100				
On table N=9							
Flip Front to Back	100	100	100				0.9
Flip Back to Front	100	92	96				2
Steps where Magazine is Opened or Closed	96	92	94		1.8	0.1	
Average of 3 Tasks Above	99	94	97				
In lap: legs uncrossed N=8							
Flip Front to Back	100	88	94				2.2
Flip Back to Front	100	100	100				3.1
Steps where Magazine is Opened or Closed	94	94	94		1.3	0.2	
Average of 3 Tasks Above	98	94	96				
In lap: legs crossed N=8							
Flip Front to Back	100	100	100				1.5
Flip Back to Front	100	88	94				2
Steps where Magazine is Opened or Closed	88	94	91		0.8	0	
Average of 3 Tasks Above	96	94	95				
In hands N=9							
Flip Front to Back	100	100	100				2
Flip Back to Front	100	83	92				0.8
Steps where Magazine is Opened or Closed	100	92	96		1.5	0.0	
Average of 3 Tasks Above	100	92	96				
Held Naturally N=8							
Flip Front to Back	100	100	100				1.1
Flip Back to Front	100	88	94				1.2
Steps where Magazine is Opened or Closed	94	94	94		1.4	0.3	
Average of 3 Tasks Above	98	94	96				

TABLE 4
RESULTS OF EXPERIMENT #2 FOR OPENING AND CLOSING OF MAGAZINES AMONG THE SINGLE-PURPOSE PROTOTYPES

	Open Score	Close Score	Overall Score		Avg under-reported open time (in secs)	Avg over-reported open time (in secs)	Avg Time (as pct) in Incorrect State
All Magazines N=45							
Flip Front to Back	95	97	96				1.8
Flip Back to Front	90	95	92				2.3
Steps where Magazine is Opened or Closed	97	96	97		4.9	0.7	
Average of 3 Tasks Above	94	96	95				
Saddle-stitched N=20							
Flip Front to Back	100	100	100				1.9
Flip Back to Front	100	100	100				2.2
Steps where Magazine is Opened or Closed	99	97	98		5	0.1	
Average of 3 Tasks Above	100	99	99				
Perfect bound N=25							
Flip Front to Back	90	95	92				1.7
Flip Back to Front	80	89	84				2.4
Steps where Magazine is Opened or Closed	96	95	96		4.8	1.3	
Average of 3 Tasks Above	89	93	91				
Longer N=10							
Flip Front to Back	80	89	84				1.3
Flip Back to Front	60	75	68				2.7
Steps where Magazine is Opened or Closed	92	93	93		4.2	2	
Average of 3 Tasks Above	77	86	81				
Shorter N=35							
Flip Front to Back	100	100	100				1.9
Flip Back to Front	100	100	100				2.2
Steps where Magazine is Opened or Closed	99	97	98		5.1	0.25	
Average of 3 Tasks Above	100	99	99				
On table N=9							
Flip Front to Back	88	100	94				1.7
Flip Back to Front	88	100	94				1.8
Steps where Magazine is Opened or Closed	98	100	99		1.94	0	
Average of 3 Tasks Above	91	100	95				
In lap: legs uncrossed N=9							
Flip Front to Back	100	88	94				1.6
Flip Back to Front	100	88	94				2
Steps where Magazine is Opened or Closed	100	92	96		5.2	0.2	
Average of 3 Tasks Above	100	89	94				
In lap: legs crossed N=10							
Flip Front to Back	100	100	100				1.9
Flip Back to Front	100	100	100				2.1
Steps where Magazine is Opened or Closed	100	97	98		4.9	0.5	
Average of 3 Tasks Above	100	99	99				
In hands N=9							
Flip Front to Back	100	100	100				1.8
Flip Back to Front	75	86	80				3.2
Steps where Magazine is Opened or Closed	92	100	96		2.2	2.5	
Average of 3 Tasks Above	89	95	92				
Held Naturally N=8							
Flip Front to Back	88	100	94				2
Flip Back to Front	88	100	94				2.5
Steps where Magazine is Opened or Closed	97	93	95		10.3	0.2	
Average of 3 Tasks Above	91	98	94				

APPENDIX A: PROTOCOLS

EXPERIMENT #1:

SEQUENCE OF 11 STEPS IN PHASES 3A TO 3C:

Turn to the page 5 pages before Ad 1
Turn to Ad 1
Turn to the page just after Ad 1
Turn to the page 5 pages after Ad 1
Turn to the page 10 pages after Ad 1
Turn to the last page of the magazine
Turn to the first page of the magazine
Turn to the page 10 pages before Ad1
Turn to the page just before Ad 1
Turn to the Ad 1
Close the magazine

Same as above for Ad 2 and the pages before and after Ad 2

Same as above for Ad 3 and the pages before and after Ad 3

TABBED PAGES:

- The page 10 pages before the page with the ad of interest
- The page 5 pages before the page with the ad of interest
- The page immediately before the page with the ad of interest
- The page with the ad of interest
- The page after the ad of interest
- The page 5 pages after the ad of interest
- The page 10 pages after the ad of interest.

EXPERIMENT #2:

SEQUENCE OF 12 STEPS IN PHASE FOR SINGLE-PURPOSE PROTOTYPES:

Open to the inside front cover
Close the magazine
Open to the point marked as ½ through the magazine
Close the magazine
Open to the point marked as ¾ through the magazine
Close the magazine
Open to the point marked as ¼ through the magazine
Close the magazine
Open to the marked as ¼ through the magazine and flip to the point ½ through the magazine
Close the magazine

APPENDIX B: ILLUSTRATIONS

Illustration #1: RFID Tag Reader

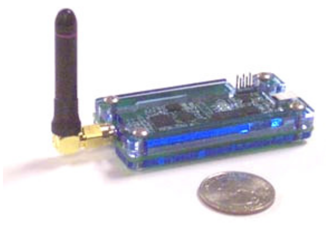

Illustration #2: Display screen for Experiment #1 showing all three marked pages closed.

Illustration #3: Display screen for Experiment #1 showing all first marked page (with Ad 1) open.

APPENDIX B: ILLUSTRATIONS (CONTINUED)

Illustration #4: Display screen for Experiment #2.