Using Mobile Phone Messaging as a Response Medium in Classroom Experiments

Stephen L. Cheung

Abstract: A major challenge in conducting classroom experiments for larger classes is the complexity of assembling responses and reporting feedback to students. The author demonstrates how mobile phone text messaging can be used to overcome the limitations of pencil-and-paper experiments without incurring the costs of full computerization. Students submit responses as text messages, which are downloaded into a spreadsheet for automated analysis and by return messaging. The author presents examples of experiments that have been conducted successfully using text messaging as the response medium. These can be run in any room from which the instructor can access the internet and are designed to economize on both class time and effort of the instructor.

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JEL codes: A20, C70, C90

Mobile phone messaging can be used to assemble and provide feedback when classroom experiments are conducted in larger classes. In a classroom experiment, students are engaged at two distinct levels: as individual subjects participating in an experiment and as analysts of the aggregate results of the experiment. As such, well-designed experiments should provide feedback to students at both levels.

In the past, this was best done by conducting experiments in fully networked computer laboratories (Williams and Walker 1993). However, because such experiments require specialized software development, their use was largely confined to instructors who conduct similar experiments for research purposes. Moreover, participation is limited by the size and availability of laboratories, and the experiments cannot be conducted in lecture theatres.

An alternative is to conduct experiments by hand, using pencil and paper. This is both time-consuming and inefficient, with aggregate results often compiled after class and reported at a later meeting. Even individual feedback can be cumbersome

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for groups exceeding 40 students, and although instructors of larger classes can group students into teams, this effectively reduces the level of participation. In some experiments, students can record individual results for themselves, but this is not the case for the game-theoretic applications I consider here. For the experiments I describe in this article, it is necessary to gather responses from individual students, match or group them anonymously, and report outcomes confidentially to each.

Although there is a compelling teaching and learning rationale for classroom experiments, their adoption has been limited by technical bottlenecks in data assembly and feedback. The challenge is to assemble student responses electronically for efficient processing and to report results promptly at both individual and aggregate levels.

HANDHELD TECHNOLOGIES FOR EXPERIMENTS

In recent years, the challenges of processing data and providing prompt feedback have led several authors to explore solutions that employ a variety of wireless handheld communications devices. I briefly review the most promising of these technologies (for a fuller discussion, see Cheung 2005).

Audience response systems (Elliott 2003) employ inexpensive handheld transmitters to collect responses from large classes—most commonly for multiple-choice questions—and generate live displays of the results on screen. Current versions of this technology suffer from a limited range of responses (constrained by the number of keys on the handset) and the lack of any facility for return communication to individual students, making them unsuitable for most applications of classroom experiments. These limitations appear likely to be resolved in a newer (and more expensive) generation of handsets, although their potential application to classroom experiments has yet to be realized.

Several authors have used handheld computers or personal digital assistants (PDAs) in conjunction with wireless networking to support classroom experiments. These applications include the WITS system described by Ball and Eckel (2004), reported to be under development toward commercial release, and the openly accessible Veconlab system developed by Holt (2007),[1] which can be accessed from a PDA using a Web browser. Compared to other handheld devices, PDAs offer superior processor power and comparatively large screens. However, their drawbacks are that few students own them,[2] and they are relatively expensive. Thus, unless their purchase is mandated, PDAs will have to be loaned by the instructor, who must bear the associated costs, including risk of theft and loss of class time.

Mobile phones are owned by the majority of students in developed countries,[3] and text messaging via short message service (SMS) is supported on all phones. To ensure that all students can participate in an experiment using SMS, the instructor need only loan handsets to a handful of students (although this was not done in the work reported here), and this can be done at minimal cost using outdated or secondhand phones with small amounts of prepaid credit. Thus, mobile phones do not suffer either the technical limitations of current audience response systems or the high costs associated with PDAs. However, a potential drawback is that students must pay network charges to send messages as part of an experiment. In the work reported here, I addressed this by offering a cash rebate, which students claimed at the end of class by displaying a return text message as evidence of participation; an alternative solution would be to establish a toll-free number for incoming messages.

SMS-MEDIATED CLASSROOM EXPERIMENTS

In Figure 1, I illustrate my use of SMS messaging technology to facilitate fully interactive classroom experiments using students' mobile phones. Students submit text messages to a designated phone number, which connects to a gateway from the mobile phone network to the internet. Incoming messages are downloaded over the internet to a personal computer, where interactions between participants are simulated on the basis of their responses. Return text messages are generated for each student to inform the student of his or her outcome in the experiment, and these are uploaded back to the gateway for broadcast to students' phones. Finally, tables of summary statistics and graphical presentations of results are generated for display on a data projector at an appropriate point in class discussion. Because individual students' handsets are used for data entry, no specialized hardware is required, and the experiments can be run in any room from which the instructor can access the internet.

I describe two simple experiments that I have successfully conducted using text messaging as the response medium. (I do not discuss here a third application, involving Cournot-style oligopoly interaction.) The experiments were run during class time in a mid-sized graduate managerial economics class (for which there was no economics prerequisite) at The University of Sydney, although the

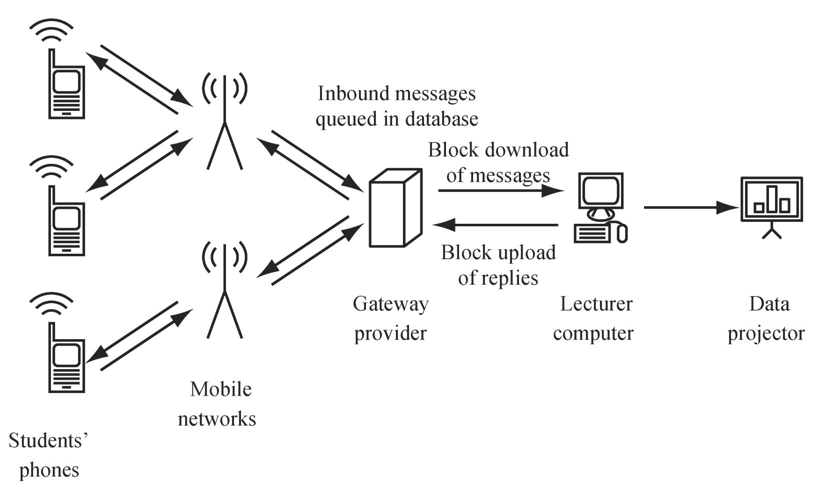

FIGURE 1. Short message services (SMS)-mediated classroom experiment.

procedure is readily scalable to much larger classes.[4] Participation in the experiments was voluntary, and performance was not graded, although a small number of participants in each experiment were randomly selected to receive cash earnings. In addition, each participant received a small payment to offset the messaging cost of participating in the experiments.

In each experiment, all analysis, manipulation, and reporting of responses were performed by a macro run within a Microsoft Excel workbook. (These programs are available on request by e-mail to the author.) Students' responses are read in as a comma separated (CSV) text file containing the originating mobile phone numbers and messages, and an output file is created in the same format containing return messages for upload and broadcast to students' phones. Message files are downloaded and uploaded by means of a Web-based interface provided by the service provider. Although the exact procedures for downloading and uploading messages may vary between providers, the programs themselves should run without modification, provided arrangements can be made to exchange messages in the required format. Thus the experiments do not depend on any specific mobile network or provider.[5]

The experiments I report here involved only 1 or 2 rounds of repetition. This is in contrast to formal experimental economics research methodology, which typically calls for 10 or more rounds. I should emphasize, however, that this was a function of the classroom setting in which the experiments were conducted, and not because of any limitation of the technology. In particular, I chose to deploy the experiments in such a way as to require an absolute minimum amount of lecture time, by displaying instructions either at the start of class or before a break and then returning to process the results immediately prior to the point at which they were to be discussed in class. However, if so desired, each of the experiments can be repeated any number of times, simply by saving additional instances of the spreadsheet used to analyze results. For example, in a dedicated 50-min session, it will be possible to complete at least 5 rounds and probably more, depending on the rate at which students' experience reduces the time required for them to submit responses. Alternatively, the same technology can be used to conduct the experiments outside class time, for example, by having a new round being triggered at a set time each day.[6]

THE ULTIMATUM GAME

The ultimatum game is one of the most famous and extensively studied experiments in game theory and experimental economics. Two strangers must negotiate the division of a sum of money (say, \$10) in a one-time interaction. Player 1 (the proponent) nominates a division of the money. Player 2 (the respondent) can only accept or refuse. If player 2 accepts, the division proposed by player 1 is implemented. If player 2 refuses, both players receive nothing. The identities of the players are unknown to each other. The standard game-theoretic prediction for this game assumes that each player seeks exclusively to maximize his or her own monetary payoff, that each player is sufficiently rational to identify the optimal strategy, and that all this is known to the other player. Under these assumptions, player 2 should accept any nonzero offer as this is preferred to refusing and receiving nothing. Knowing this, player 1 will make the smallest permissible offer to player 2 (say, a $1 share of $10) in anticipation that this will be accepted. However, an extensive body of experimental literature (see Thaler [1988] for a survey) consistently fails to support the predictions of this simple theory. In particular, respondents frequently refuse small offers, whereas proponents typically offer a close-to-equal division of the money. Because one explanation for this behavior centers on fairness, the ultimatum game is ideal for motivating discussion on the issue of fairness as well as the success or otherwise of game theory as a tool of prediction.

A classroom implementation of the ultimatum game is described by Dickenson (2002). However, he noted that

> Because this experiment involves physically transferring messages back and forth between proposers and responders, it is probably best for classes of 40 students or fewer (a teaching assistant may prove useful for this experiment). (p. 138)

In a larger class setting, Dickenson's implementation of the ultimatum game is cumbersome for several reasons. First, it is necessary that there be exactly equal numbers of proponents and respondents. Second, the instructor or teaching assistant must not only physically transfer messages between proponents and respondents but also keep track of how these are matched so that acceptance or rejection decisions can be returned. Third, the fact that decisions are made sequentially adds to the time taken to complete the experiment. Finally, although Dickenson's procedure generates feedback to individual participants during the course of the experiment, it does not produce aggregate results for use in class discussion. If the latter are required, they must be compiled outside class for discussion in a subsequent class meeting.

In the SMS version of the ultimatum experiment, I adopt a simultaneous-move version of the game as studied by Harrison and McCabe (1996). As before, the role of player 1 is to make an offer to player 2. However, player 2 is now asked to nominate the minimum offer he or she is willing to accept. If the offer proposed by player 1 is greater than or equal to the minimum sought by player 2, then it is implemented; otherwise, both players receive nothing. On eliminating weakly dominated strategies of the respondent, the surviving Nash equilibrium of this simultaneous-move game is that in which the proponent makes the smallest permissible offer, and this is accepted by the respondent.[7] Although Harrison and McCabe had a specific research rationale for adopting this form of the game, my intent here is primarily to economize on time and simplify the processing of text messages.

Instructions for the SMS ultimatum experiment are set out in Appendix A. In the first round, students whose mobile phone numbers end in an odd number were assigned the role of player 1 (proponent) and instructed to text in an integer between 1 and 9, being the amount offered to player 2. Students with even-numbered phone numbers were assigned the role of player 2 (respondent) and instructed to text in an integer representing the minimum offer they were willing to accept. In a second round of the game, the roles of the two groups were reversed.

After students' responses were downloaded, an Excel macro sorted them into proponents and respondents, filtered invalid responses,[8] and generates summary statistics and graphical presentations of the results. In Figures 2 through 5, I show results from the second round of a trial of this experiment conducted at The University of Sydney in March 2004. I discuss their interpretation and use in discussion in further detail later. Students were informed at the start of the game that two pairs of students would be selected in each round to play for real cash payoffs. A total of 47 valid responses were received, from 23 proponents and 24 respondents.[9] Figures 2 through 5 are presented in the form they were generated by the spreadsheet macro; these figures were thus available to be displayed to students for use in discussion immediately upon conclusion of the experiment.

In addition to producing the aggregate results shown in Figures 2 through 5, the spreadsheet macro automatically generates random matches of individual proponents and respondents. If the amount offered by the proponent is greater than or equal to the minimum amount the respondent was willing to accept, a return text message is automatically generated to inform each that an agreement was reached. Conversely, if no agreement is reached, return messages to that effect are generated instead.[10] This would otherwise be a highly complex and time-consuming task in a larger class setting. In the event that there are unequal numbers of proponents and respondents, each unmatched player is automatically paired with a randomly redrawn player of the other type, but the outcome of this pseudomatch is reported back only to the player who was originally unmatched. In the experiment I report here, this means that the unmatched 24th respondent is paired with a random draw from the distribution of 23 proposal values, and this is how their agreement outcome and payoff are generated. Finally, the macro computes the percentage of participants who reached agreement in the simulation. Because any outcome that

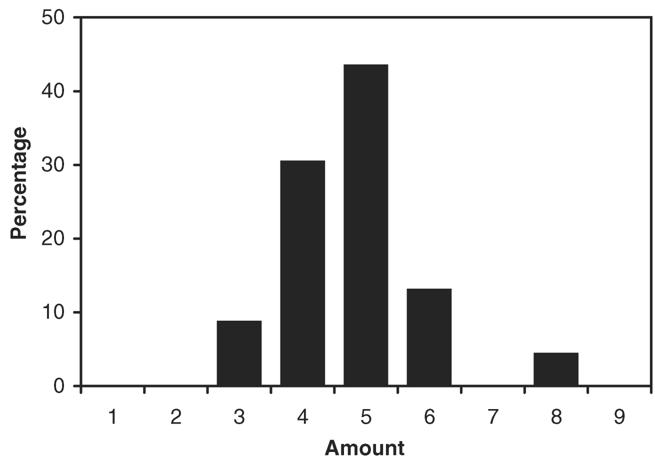

FIGURE 2. Ultimatum game: Frequency distribution of proposal values.

results in agreement is efficient, this figure also represents the realized level of efficiency. For the experiment reported here, this figure was 82 percent.

Simple frequency distributions (Figures 2 and 3) show the responses submitted by proponents and respondents, respectively. These are used in postexperiment discussion to introduce students to the major issues raised by this experiment. They show, first, that the results appear not to match closely with the simple game-theoretic predictions outlined above. On the other hand, they are broadly consistent with results reported elsewhere in the research literature, with both the proposal and the acceptance values clustered around 4 and 5. That is to say, respondents are willing to reject small offers, whereas proponents tend to offer a near-equal split (there are also a fair number of larger offers, a point to which I return later).

These observations can then be used to introduce a discussion of current debates in the research literature over how to best reconcile the predictions of standard theory with the experimental evidence. Because three assumptions are made in generating the standard prediction, one can conceive of three possible violations. Subjects may be motivated by considerations other than their own monetary payoffs, they may have difficulty discerning their optimal strategy, or they may lack knowledge of the objectives or rationality of their opponents. The first possibility leads to explanations that generalize preferences to incorporate concerns for fairness or reciprocity, and the second and third lead to explanations that emphasize incomplete learning.

In discussing the competing perspectives within the research literature, the analysis presented in Figure 4 may be particularly instructive. In this figure, the line graph shows the probability that a proponent reaches agreement as a function of the amount of the offer, given the distribution of threshold values as demanded

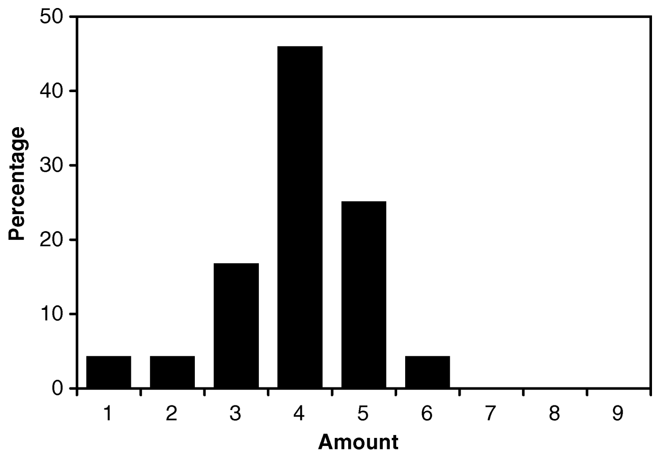

FIGURE 3. Ultimatum game: Frequency distribution of acceptance values.

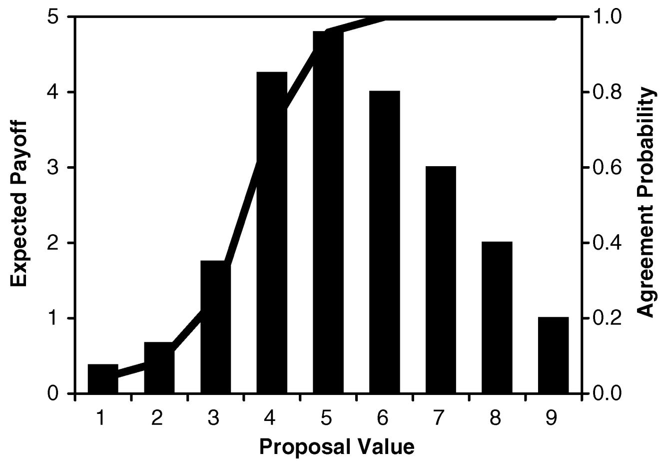

FIGURE 4. Ultimatum game: Expected payoffs and agreement probabilities for proponents.

by the population of respondents. Naturally, the probability of reaching agreement increases monotonically with the amount offered. However, as proponents increase the amount of their offer, they also reduce their realized payoff in the event of agreement. Thus proponents face a trade-off between the probability of agreement and their payoff in the event of agreement. Weighing these two effects, the bar chart in Figure 4 shows expected payoffs to a proponent, under the assumption of risk neutrality. What this shows is that *given the distribution of responses of the respondents*, the strategy that maximizes the expected payoff of a player 1 is to offer an equal division of the money and not to make the minimum permissible offer as suggested by simple theory. Thus, it may not be necessary to resort to regard for fairness to explain the behavior of proponents. Further, if a proponent is risk averse, then he or she will be willing to trade off a smaller expected payoff for a higher probability of agreement. This may explain why some proponents were willing to offer more than a half share to the respondent. Indeed, in the game reported here, a proponent who offers 6 is certain to reach agreement and thus attains a sure payoff of 4.[11]

The line and bar graphs in Figure 5 provide a corresponding analysis for the respondents. Naturally, the probability of reaching agreement declines monotonically with the minimum amount sought by the respondent. But because the realized payoff in the event of an agreement is determined by the amount offered by the proponent, a respondent's behavior can affect only the probability of agreement and not the payoff. It follows that a respondent's expected payoff also declines monotonically with the acceptance threshold. Thus, it is difficult to explain why respondents would hold out for a near-equal split without invoking considerations of fairness or incomplete learning.[12] However, the bar chart in Figure 5 suggests

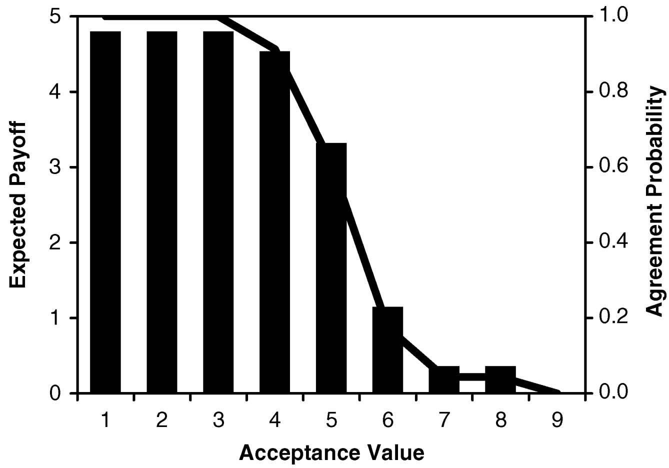

FIGURE 5. Ultimatum game: Expected payoffs and agreement probabilities for respondents.

that *given the distribution of offers made by the proponents*, the cost in expected value terms to a respondent of holding out for the modal demand of 4, as opposed to simply accepting all offers, is quite small.

THE VOLUNTARY CONTRIBUTION GAME

The voluntary contribution game is another experiment that has been widely studied in the research literature, and it was among the first research experiments to be adapted to the classroom. In this experiment, each participant is given an endowment of m tokens and is randomly assigned to a group of N players. Each player's problem is to divide his or her the endowment between two pools that, following Leuthold (1993), I label neutrally as pool A and pool B to avoid biasing decisions. Returns to pool A accrue only to the individual making an allocation to that pool. Returns to pool B depend on the total group contribution and are shared equally among all members of the group regardless of whether they contribute. Thus, pool B is a pure public good, and those who invest in A can free ride on others' contributions to B.

Payoffs are constructed such that the social return to the public good B exceeds that from the private good A. However, each individual's share of the return to B is such that it is privately optimal to invest in A. In particular, let x_i be player i's allocation to A, let v be the private return to each token allocated to A, and let w be the group return to each token allocated to B, such that w/N is the share paid to each member. Then player i's monetary payoff is $u_i = vx_i + \frac{w}{N}\sum_j (m - x_j)$ so, provided $v > w/N$, it is privately optimal for a money-maximizing player to choose $x_i = m$ regardless of the actions of the other players.[13] On the other hand, the total monetary payoff to the group is $W = v \sum_j x_j + w \sum_j (m - x_j) = wNm - (w - v) \sum_j x_j$ so provided $w > v$, it is socially optimal for the entire endowment to go into the public good, that is, $x_i = 0$. Thus for $w > v > w/N$ a prisoners' dilemma arises in which free riding is the dominant strategy, resulting in underinvestment in the public good and a socially suboptimal outcome.

A fully computerized classroom implementation of this game is described in Williams and Walker (1993), and a paper-based version is found in Leuthold (1993).[14] As was the case in the ultimatum game, players are assigned to groups anonymously, and the decisions of several players must be aggregated to compute payoffs and report results and feedback to each student. In the paper-based version described by Leuthold, this is done by compiling results after class for discussion at a later meeting. This obviously results in a loss of immediacy; moreover, Leuthold's procedure reports only aggregate results and not feedback on payoffs to individual students. Both of these limitations can be overcome through the use of text messaging, without the need to resort to a fully computerized experiment.

Instructions for the SMS contribution game are set out in Appendix B. For the experiment reported here, the parameter values were $m = 10$, $N = 5$, $v = \$0.20$, and $w = \$0.50$. Thus, for each token allocated to pool B, the individual return from the private pool A declined by \$0.20, and the group return from the public pool B increased by \$0.50. However, because an individual's share of the return to pool B was only \$0.10, a private money-maximizing player should choose pool A. Several other aspects of the experiment reported here should be noted. First, because of scheduling constraints, the game was conducted shortly after students had finished discussing simple two-player, two-strategy prisoners' dilemma games.[15] Second, to save the time and cost of a multiple-round experiment, students worked through a set of warm-up exercises before submitting their responses in a one-shot game.[16] These exercises were intended to act like a learning phase, thereby reducing any noise in the results caused by confusion over the structure or incentives of the game. Third, the instructions explicitly stipulated that a student's goal was to maximize his or her individual earnings.[17] Finally, assuming players to be rational money maximizers, the conditions of a one-shot game with anonymous groupings should in principle maximize the incentive for free riding, because opportunities for reputation building and reciprocal altruism arise only in repeated game settings.[18]

Students are instructed to text in an integer between 0 and 10, representing the number of tokens they wish to allocate to pool A (the private good). Once these responses have been downloaded, they are processed in a manner analogous to that described previously for the ultimatum game. Any invalid responses are discarded, and summary statistics and graphical displays of aggregate results are compiled for use in classroom discussion. Students are then randomly assigned to groups of five, and their payoffs are computed as a function of the group allocation to pool B. This information is saved to an output file containing return text messages, ready for upload and broadcast back to students' phones.[19] Should the total number of responses not be divisible by five, the remaining participants are matched with randomly redrawn members of the class for the purpose of computing their group allocation to pool B. All this is done automatically by the spreadsheet macro in a matter of seconds.

In Figures 6 and 7, I show results of a trial of this experiment conducted in February 2005. As indicated in the instructions, students were told that one group would be selected at random to play for real cash earnings. Of 48 students present in class, valid responses were received from 42 students or 88 percent.[20] Figure 6 shows the frequency distribution of students' allocations to the private good A. Whereas the

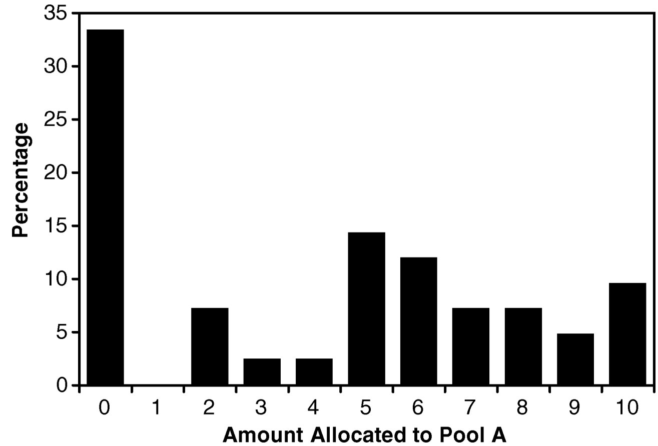

FIGURE 6. Voluntary contribution game: Frequency distribution of allocations to private good.

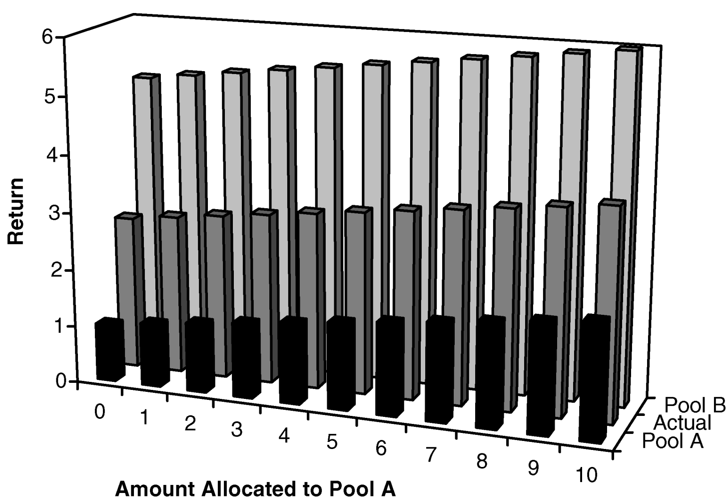

FIGURE 7. Voluntary contribution game: Graphical depiction of payoffs.

strong prediction of theory is that money-maximizing players will free ride, the modal response (as chosen by one-third of participants) was to allocate the entire endowment to the public good B. A further one-quarter of students elected to split their endowments roughly equally, and fewer than 15 percent chose near-total free riding. In aggregate, the students allocated 176 tokens or 42 percent of their total endowment to the private pool A, and total earnings in the simulated groupings were \$158.40, representing a realized efficiency of 75 percent of the total that could have been attained ($wNm = \$210$) had everyone chosen the public pool B. These results are broadly consistent with the findings surveyed in Dawes and Thaler (1988), in which contributions to the public good typically range between 40 and 60 percent.

The data in Figure 7 show an individual's payoff as a function of his or her allocation to the private good A along the horizontal axis. Payoffs on the front row correspond to a situation where the other four group members allocate all their endowment to pool A, and entries along the back row represent a situation where the other players allocate everything to pool B. The middle row shows expected payoffs under random assignment to groups, given the actual behavior of all students in the class. This presentation is used in class discussion to highlight the key features of incentives in this game. Reading from left to right, for given strategies of the remaining group members, an individual's payoff increases with the amount he or she allocates to the private pool A. This presentation provides a clear visual illustration of the incentive to free ride. Reading from front to back, for any given strategy of the individual, his or her payoff increases with the amount allocated by the others to the public pool B. This highlights the fact that when all players recognize and follow their dominant strategies, the result is a lower payoff to all players compared to a situation where they all choose pool B.

Contrary to the standard prediction of full noncooperation, it is clear that many students were willing to allocate a substantial portion of their resources to the public good B. This observation can be used as an entry point into a discussion of recent experimental research on voluntary public goods provision.[21] A number of regularities emerge from this literature. For example, contributions are found to decline with repeated interaction, although there is little consensus on the issue of whether cooperation is greater when players interact repeatedly within one group or when they are rematched between rounds. When participants are permitted to talk to one another, contributions to the public good are found to increase. Imposing a "provision point" (a minimum threshold for group contributions before any return is earned from the public good) has the effect of increasing contributions. Should the instructor be in a position to dedicate a full hour of class time to this experiment, it will be possible to generate some of these results through repetition.[22] The availability of technologies such as SMS messaging makes this more manageable, less time-consuming, and feasible for larger classes than traditional methods of conducting classroom experiments.

CONCLUSION

Classroom experiments represent one of the most significant and promising developments in the pedagogy of economics over the past decade. However, their adoption has been limited by essentially technical obstacles in assembling data and reporting feedback in larger classes without resorting to a full network of computers. The experiments I report here demonstrate how a combination of mobile phone messaging and spreadsheet processing can overcome the limitations of pencil and paper without incurring the costs of fully networked experiments. In particular, the use of text messaging streamlines the process of electronic data assembly and analysis, enabling the generation of results and feedback to be automated by a spreadsheet. Moreover, because these experiments have been designed to economize on both class time and effort to the instructor, they can be readily integrated into large lecture classes.

NOTES

1. Available at http://veconlab.econ.virginia.edu/admin.htm.
2. In a study of 18,039 undergraduates at 63 U.S. institutions, Kvavik and Caruso (2005) found that only 12.6 percent report owning PDAs, compared with 90.1 percent for mobile phones.
3. In the voluntary contribution experiment reported in a later section, at most 6 percent of students did not have mobile phones or did not bring them to class on the day of the experiment. In addition to the Kvavik and Caruso (2005) finding, further international evidence on mobile phone and text messaging usage among college-age adults may be found in A. T. Kearney (2002).
4. For the experiments reported here, SMS service was provided by a carrier that regularly supports such applications as voting on nationally networked television programs. Thus, the load created by even the largest of undergraduate classes would appear unlikely to challenge this system.
5. As the required upload-and-broadcast facility was not available from any Australian provider, custom software development was commissioned to implement it at a cost of A$2,000. SMS service was provided by LegionONE (http://www.legionone.com/), with the upload feature implemented as an add-in to the XpresSMS application. In addition to software development and setup costs, a monthly service fee is charged to maintain the service, and outgoing text messages sent from the system are billed.
6. This aspect is implemented quite naturally in the XpresSMS application, because the upload and broadcast of return messages from one round of an experiment automatically triggers the creation of a new table in which incoming messages for the next round can be stored. The application also permits the instructor to specify set time limits within which messages may be accepted for each round of an experiment.
7. Note that psychologically this game is not, strictly speaking, an ultimatum, because player 2 does not respond to an actual offer. The existing literature tends to overlook this distinction; the two games would not be equivalent for the purposes of neuroeconomic studies such as Sanfey et al. (2003). I am grateful to Chris Geller for this observation.
8. A valid response in this game is simply one that contains a nonzero numeral. Thus "$5," "Give 4 to player 2," and "Minimum 1 dollar" are all actual examples of messages that are interpreted correctly by the macro. However, a response of "One" is rejected as invalid and results in a return text message stating "Error: you must submit a numeral between 1 and 9." I did not observe any evidence of students submitting spurious messages that were unrelated to the game.
9. Unfortunately, I did not record the number of students present in class on the day of this experiment, so it was not possible to compute a response rate. However, see the subsequent discussion of the voluntary contribution game in the next section.
10. For example, if player 1 offers $4 and player 2 demands $5, no agreement is reached. Player 1 receives the return message: "You are player 1. You offered $4, but player 2 wanted $5. No agreement reached." Player 2 receives the return message: "You are player 2. You wanted $5, but player 1 offered $4. No agreement reached."
11. Figure 2 also shows one student who made an offer of 8. It is possible that this student may simply have misunderstood the instructions.
12. Many creative approaches have been suggested for identifying the individual effects of fairness versus learning in ultimatum games, including Forsythe et al. (1994), Harrison and McCabe (1996), Andreoni, Castillo, and Petrie (2003), Andreoni and Blanchard (2006), and Brenner and Vriend (2006).

13. Note that because this is a dominant strategy, this prediction makes weaker demands on each player's knowledge of the objectives and rationality of the other players than was the case in the ultimatum game.
14. In Leuthold's version of the game, *N* is simply the entire class.
15. Although this might invalidate the results for research purposes, the effect on student learning is arguably benign. This is because students are being challenged to transfer their knowledge to a setting in which there are more players, more strategies, and the incentive structure is less transparent than in a standard prisoners' dilemma game.
16. One of the referees has queried the use of a single-shot design. I believe this is partly a matter of pedagogical style as well as one of experimental design. As noted earlier, I devised these experiments to fit into a lecture-based class at minimal expense in terms of time. Leuthold (1993) and Sulock (1990) both described single-shot public goods games, which they incorporate into their classes in a similar manner. By contrast, instructors who are also experimental researchers often prefer to set aside dedicated blocks of time to each experiment, during which they conduct multiple rounds. This permits the effect of learning to be incorporated in the results to a greater extent than in the experiments described here. Because the SMS technology can support any number of rounds, it can also be used to conduct experiments in this manner.
17. This is arguably more benign than issuing the same instruction in an ultimatum game, but it may again invalidate the results for research purposes. Naturally, instructors who are uncomfortable with this instruction are free to omit it. The intent was to reduce noise by encouraging students to sharpen their reasoning before submitting responses. One of the referees objects that this may be "stacking the deck," presumably in favor of free riding. It is thus interesting to note that the results nonetheless indicate quite high levels of cooperation.
18. It is well known that cooperation can be supported using trigger strategies in infinitely repeated prisoners' dilemma games. In addition, Kreps et al. (1982) argue that cooperation may also be rational in the early stages of a finitely repeated game, when playing against an opponent who, it is believed, may be irrational.
19. For example, if the five members of group 4 choose to allocate 5, 8, 7, 0, and 5 tokens to pool A, then the first student receives the return message: "Group 4. You allocated 5 tokens to Pool A. Your group allocated a total of 25 tokens to Pool B. Your payoff is $3.5." The group number is used to identify the students to receive earnings in cash.
20. The experiment was launched at the start of a break at the midpoint of the class, and responses were received over a period of seven minutes. Subsequent analysis of message logs identified an additional three students who submitted responses that were not accepted because they were submitted after replies had been sent back to the other participants. No invalid responses were received. Thus responses were submitted by 94 percent of the class. In light of the large-scale survey evidence reported by A. T. Kearney (2002) and Kvavik and Caruso (2005), I conjecture that response rates would be similar in an undergraduate class.
21. Recent surveys of this literature are provided by Anderson (2001) and Andreoni and Croson (forthcoming). In addition to the results noted in the text, a focus of research has been to distinguish behavior driven by nonegotistical, other-regarding preferences (kindness) from that caused by incomplete learning (confusion), because either hypothesis may explain why many participants do not free ride. This mirrors the earlier discussion of the ultimatum game.
22. Note, however, that the procedure described in this article does not currently support repeated interactions within fixed groupings of students. That is, students are always randomly rematched in each round of the game.

REFERENCES

Anderson, L. R. 2001. Public choice as an experimental science. In *The Elgar companion to public choice*, ed. W. Shugart and L. Razzolini. 497–511. Cheltenham, England: Edward Elgar.

Andreoni, J., and E. Blanchard. 2006. Testing subgame perfection apart from fairness in ultimatum games. *Experimental Economics* 9 (4): 307–21.

Andreoni, J., M. Castillo, and R. Petrie. 2003. What do bargainers' preferences look like? Experiments with a convex ultimatum game. *American Economic Review* 93 (3): 672–85.

Andreoni, J., and R. Croson. Forthcoming. Partners versus strangers: Random rematching in public goods experiments. In *Handbook of experimental economics results*, ed. C. Plott and V. L. Smith. Amsterdam: Elsevier.

A. T. Kearney Inc. 2002. *Mobinet index #5*. http://www.atkearney.com/shared_res/pdf/Mobinet_5_S.pdf.

Ball, S. B., and C. C. Eckel. 2004. Using technology to facilitate active learning in economics through experiments. *Social Science Computer Review* 22 (4): 469–78.
Brenner, T., and N. J. Vriend. 2006. On the behavior of proposers in ultimatum games. *Journal of Economic Behavior and Organization* 61 (4): 617–31.
Cheung, S. L. 2005. Mobile simulation gaming in economics education: Progress and prospects. In *Mobile learning 2005*, ed. P. Isaias, C. Borg, P. Kommers, and P. Bonanno. Lisbon, Portugal: IADIS.
Dawes, R. M., and R. H. Thaler. 1988. Anomalies: Cooperation. *Journal of Economic Perspectives* 2 (3): 187–97.
Dickenson, D. L. 2002. A bargaining experiment to motivate discussion on fairness. *Journal of Economic Education* 33 (2): 136–51.
Elliott, C. 2003. Using a personal response system in economics teaching. *International Review of Economics Education* 1 (1): 80–86.
Forsythe, R., J. L. Horowitz, N. E. Savin, and M. Sefton. 1994. Fairness in simple bargaining experiments. *Games and Economic Behavior* 6 (3): 347–69.
Harrison, G. W., and K. A. McCabe. 1996. Expectations and fairness in a simple bargaining experiment. *International Journal of Game Theory* 25 (3): 303–27.
Holt, C. A. 2007. *Markets, games, and strategic behavior*. Boston: Addison-Wesley.
Kreps, D. M., P. Milgrom, J. Roberts, and R. Wilson. 1982. Rational cooperation in the finitely repeated prisoners' dilemma. *Journal of Economic Theory* 27 (2): 245–52.
Kvavik, R. B., and J. B. Caruso. 2005. *ECAR study of students and information technology 2005: Convenience, connection, control, and learning*. Boulder, CO: Educause Center for Applied Research.
Leuthold, J. H. 1993. A free-rider experiment for the large class. *Journal of Economic Education* 24 (3): 353–63.
Sanfey, A. G., J. K. Rilling, J. A. Aronson, L. E. Nystrom, and J. D. Cohen. 2003. The neural basis of economic decision-making in the ultimatum game. *Science* 300 (5626): 1755–58.
Sulock, J. M. 1990. The free rider and voting paradox "games." *Journal of Economic Education* 21 (1): 65–69.
Thaler, R. H. 1988. Anomalies: The ultimatum game. *Journal of Economic Perspectives* 2 (4): 195–206.
Williams, A. W., and J. M. Walker. 1993. Computerized laboratory exercises for microeconomics education: Three applications motivated by experimental economics. *Journal of Economic Education* 24 (3): 291–315.

APPENDIX A

Instructions for Ultimatum Experiment

Two strangers are arguing over a $10 note they have found on the footpath.

Player 1 can offer to give \$$X$ to the other player (and thus keep \$(10–X) for himself). X must be an integer between 1 and 9.

Player 2 can accept or reject the offer from Player 1.

- **If Player 2 accepts**, each player receives the amount proposed by Player 1: \$(10 – X) for Player 1, and \$$X$ for Player 2.
- **If Player 2 rejects**, they each get nothing.

After this, the game ends and the two players never meet again.

ROUND 1

If the last digit of your mobile phone number is odd (i.e., 1, 3, 5, 7, or 9), you are Player 1.
Write down the value of X you propose to offer the other player.
Example: If you write 2, you propose to give $2 to the other player, and keep $8 for yourself.
X must be an integer between 1 and 9.

If the last digit of your mobile phone number is even (i.e., 0, 2, 4, 6, or 8), you are Player 2.
Write down the *minimum* value of *X* you are willing to accept.
Example: If you write 4, you accept an offer of $4, but refuse an offer of $3.
X must be an integer between 1 and 9.

SMS your answer to xxxx xxx xxx.
(There is no need to include the "$")

ROUND 2

If the last digit of your mobile phone number is even (i.e., 0, 2, 4, 6, or 8), you are Player 1.
Write down the value of *X* you propose to offer the other player.
Example: If you write 2, you propose to give $2 to the other player, and keep $8 for yourself.
X must be an integer between 1 and 9.
If the last digit of your mobile phone number is odd (i.e., 1, 3, 5, 7, or 9), you are Player 2.
Write down the *minimum* value of *X* you are willing to accept.
Example: If you write 4, you accept an offer of $4, but refuse an offer of $3.
X must be an integer between 1 and 9.

SMS your answer to xxxx xxx xxx.
(There is no need to include the "$")

APPENDIX B

Instructions for Voluntary Contribution Experiment

In this game, each student will be randomly assigned to a five-player group.
Each player has 10 tokens, which they can allocate to either of two pools:

- Each token allocated to **Pool A** earns a return of ***20 cents****, to be paid to the individual student who owns the token.*
- Each token allocated to **Pool B** earns a return of ***50 cents****, to be divided equally between all five members of the group.*

Returns from Pool A accrue only to the students who own the tokens. However, all students earn a share of total group returns from Pool B, regardless of whether they allocate any tokens to it or not.
You do not know the identities of the other members of your group.
You may divide your tokens between the two pools as you please, provided you do so in **whole units**.
Your objective is to do this so as to maximize your own individual earnings.
One group will be selected at random to receive their earnings in cash. All other earnings are hypothetical.

WARM-UP EXERCISES

Suppose that:

- You allocate 3 tokens to Pool A.
- The other four members of your group allocate a total of 12 tokens to Pool B.

What is the total group allocation to Pool B? What is your return from Pool A? What is your share of the group return from Pool B? What is your total return?
Now suppose that:

- You allocate 7 tokens to Pool A.
- The other four members of your group allocate a total of 28 tokens to Pool B.

What is the total group allocation to Pool B? What is your return from Pool A? What is your share of the group return from Pool B? What is your total return?

WHAT WILL YOU DO?

Choose an integer between 0 and 10, representing the **number of tokens you wish to allocate to Pool A**. The rest of your tokens will be allocated to Pool B.

SMS your answer to xxxx xxx xxx.
(Do not include any other text or symbols in your response.)