

# The Timing of Bids in Internet Auctions: Market Design, Bidder Behavior, and Artificial Agents<sup>\*</sup>

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## Abstract

Many bidders in eBay employ bidding strategies that involve late bids, incremental bids, or both. Based on field evidence, we discuss the manner in which late bids are caused both by sophisticated, strategic reasoning, and by irrationality and inexperience, and how late bidding interacts with incremental bidding. The relation between market design and artificial agent design is discussed.

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## **I. Human and automatic bidding in online auctions**

Game theorists and market designers focus on the impact of the rules of the game on the behavior of the participants. Participants in internet markets may be human bidders bidding in person, or artificial agents employed by bidders. Thus, the performance of market rules depends on what behavior the rules elicit from human and artificial agents. At the same time, the performance of software agents, and the decisions of bidders whether to use them, depend on how they interact with humans and other software agents in the market. So, market design and artificial agent design are closely related.

In this paper, we report on an ongoing study of internet auctions. We focus here on how a small difference in the rules employed in auctions run by eBay and Amazon, both of which supply bidders with simple software agents, elicit different behavior from bidders, and different use of software agents. We will briefly consider how these issues look from the perspectives of the buyers, the sellers, the market makers (the auction houses), and from the perspective of third party suppliers of software agents. (The results and data discussed here are taken from Ariely et al., 2001, Ockenfels and Roth, 2001, and Roth and Ockenfels, forthcoming).

One of the big attractions of internet auctions is that buyers do not all have to gather at the same place to participate, so that sellers can use internet auctions to sell even relatively low value items to a potentially wide audience. But the size of the market would be limited if all potential bidders had to be online at the same time, and for this reason most auctions are conducted over a period of days, often a week. To make it simple for bidders to participate in a week long auction, without having to be constantly vigilant, or to be online at the close of the auction, most internet auction houses make available a simple kind of software bidding agent, that eBay calls “proxy bidding.”

eBay asks the bidders to submit maximum bids (called “proxy bids”) and explains that “eBay will bid incrementally on your behalf up to your maximum bid, which is kept secret from other eBay users.” That is, once a bidder submits his “maximum bid,” his resulting bid registers as the minimum increment above the previous high bid. As subsequent proxy bids by other bidders come in, the bid of the bidder in question automatically rises by the minimum increment until the second highest submitted proxy bid is exceeded (or until his own maximum is exceeded by some other bidder). At the end of the auction, the bidder who submitted the highest proxy bid

wins the object being auctioned and pays a price that is a small increment above the second highest maximum (proxy) bid.

To understand the bidding behavior that the proxy bidding system elicits, it will help to first consider how different the auction would be if, instead of informing all bidders about the bid history at each point of time during the auction, the auction were a *second price sealed bid auction* (in which nobody is informed about the proxy bids of other bidders until the auction is over). Then, the proxy bidding agent provided by eBay would make incremental or multiple bidding unnecessary. Suppose for instance that your maximum willingness to pay for an antique coin auctioned on eBay were \$100. Then, bidding your maximum willingness to pay in a second price sealed bid auction is your dominant strategy, i.e., you can never do better than by bidding \$100. The reason is that your proxy bid does not affect the price of the coin in case you win the auction (recall that the price is determined by the second highest proxy bid). Your proxy bid only determines whether you win the auction or not. If you submit your maximum willingness to pay, you will win the auction if and only if your maximum is higher than the price, so there is no reason to over- or understate your willingness to pay.<sup>1</sup>

eBay explains the economics of second price auctions to their bidders along these lines, and extends the conclusion to its own auctions, in which bids are processed as they come in: “eBay always recommends bidding the absolute maximum that one is willing to pay for an item early in the auction. (...) If someone does outbid you toward the last minutes of an auction, it may feel unfair, but if you had bid your maximum amount up front and let the Proxy Bidding system work for you, the outcome would not be based on time.” The underlying idea is, of course, that eBay’s bidding agent will bid up to the maximum bid only when some other bidder has bid as high or higher. If the bidder has submitted the highest proxy bid, he wins at the “lowest possible price” of one increment above the next highest bid.<sup>2</sup> So, similar to the second price sealed bid auction described above, at the end of the auction a proxy bid wins only if it is the highest proxy bid, and the final price is the minimum increment above the second highest submitted proxy bid,

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<sup>1</sup> In case two bidders are tied for the highest bid, the one who submitted it first is the winner. Vickrey (1961) offered the first theoretical analysis of the sealed bid second price auction. Since then, economists often refer to the sealed bid second price auction as a “Vickrey-auction”.

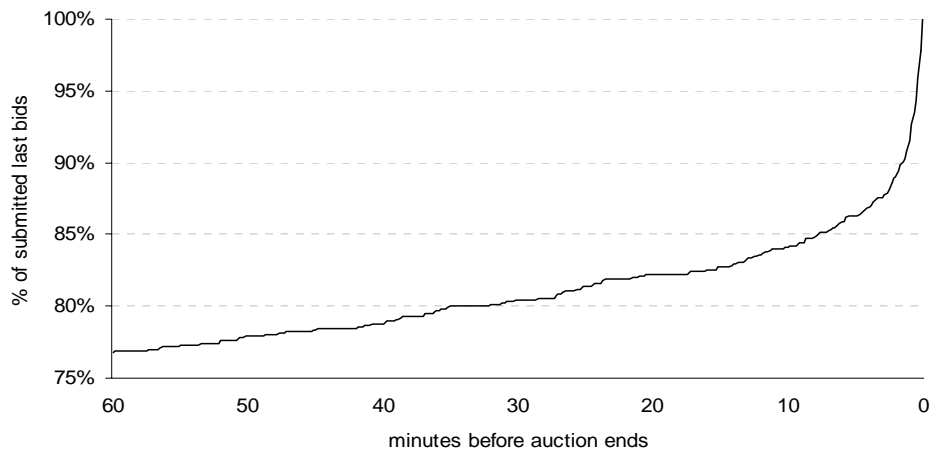
<sup>2</sup> If one increment above the second highest proxy bid exceeds the highest proxy bid, then the high bidder wins at the amount of his proxy bid.

regardless of the timing of the bid. As we will show below, however, proxy bidding does not necessarily remove the incentives for late or incremental bidding in these second price auctions in which bids are processed as they come in, nor do bidders behave as if they thought it did.

## II. A first look at bidding behavior

Looking at the bid histories of completed auctions on eBay, two common properties of bidding strategies become quickly evident. First, a substantial fraction of (human or artificial) agents submit their bids in the closing seconds of an auction, a practice called “sniping.” Second, many bidders bid multiple times, which means that they increase a maximum bid submitted earlier in the auction.

Figure 1 shows the empirical cumulative probability distribution of the timing of bidders' last bids in a sample of 308 eBay auctions of computers and antiques with a total of 1339 bidders. It illustrates that, although eBay-auctions usually last one week, many bidders bid in the very last minutes of the auctions. For instance, 14 percent of all bidders in this sample submitted their final bids in the last five minutes, 9 percent in the last minute, and more than 2 percent in the last ten seconds before the deadline.



**Figure 1.** Cumulative distributions of bidders' last bids over time (Ockenfels and Roth, 2001)

So at least some bidders like to bid late, sometimes very late. A survey of late bidders reported in Roth and Ockenfels (forthcoming) revealed that most are bidding late by hand, which

requires them to be online at the end of the auction. But because this involves a good deal of planning and effort, there is a market for “sniping agents” that will allow a bidder not only to submit a proxy bid, but to do so at the last moment. These take two forms: downloadable programs that run on the bidder’s own computer, and web based services to which a bidder can subscribe. Both offer bidders the ability to decide on their maximum bid early in the auction, record when the auction is scheduled to end, and decide how many minutes or seconds before the end of the auction the sniping agent should (attempt) to submit the bid.

One of the most interesting of these bidder agents is the web based service [esnipe.com](http://esnipe.com). It was originally developed as a free service, and after building up a user base it was sold, at auction, on eBay. The auction began on November 21, 2000, and was scheduled to end precisely ten days later, on December 1. Figure 2 shows the bid history. Note that the auction ended at precisely 18:08:38 Pacific Standard Time. The very first bid in this ten day auction was entered on day ten of the auction, the last day. And the last three bids, including the bid that won the auction at a final price of \$35,877.77, came in the last minute during which time the price rose over \$10,000, from \$25,300 (one increment over the second highest bid one minute before the end).

eBay Bid History for  
 esnipe.com - complete online sniping site (Item #506328272)

Currently	\$35,877.77	Part bid	\$20,000.00
Quantity	1	# of bids	8
Time left	<b>Auction has ended.</b>		
Started	Nov-21-00 18:08:38 PST		
Ends	Dec-01-00 18:08:38 PST		
Seller (Rating)	<a href="#">esnipe</a> (5)		

[View page with winning bidder\(s\) email address](#) (Accessible by Seller only) [Learn more.](#)

Bidding History (Highest bids first)

User ID	Bid Amount	Date of Bid
<a href="#">tomcam</a> (16) ★	\$35,877.77	Dec-01-00 18:08:24 PST
<a href="#">vroom42</a> (18) ★	\$35,777.77	Dec-01-00 18:08:34 PST
<a href="#">redstuartwark</a> (233) ☆	\$35,158.67	Dec-01-00 18:07:47 PST
<a href="#">gr@meta4</a> (0)	\$32,500.00	Dec-01-00 18:07:20 PST
<a href="#">dglawrence</a> (8)	\$25,200.00	Dec-01-00 18:07:42 PST
<a href="#">tomcam</a> (16) ★	\$25,000.00	Dec-01-00 18:05:24 PST
<a href="#">cpalmer</a> (1214) ★	\$23,011.00	Dec-01-00 10:34:01 PST
<a href="#">dglawrence</a> (8)	\$20,100.00	Dec-01-00 17:52:56 PST

Figure 2: The bid history of the auction of esnipe.com

Note, incidentally, that the winning bid was not the last bid; the winning bid came in ten seconds before the last bid, but with a higher proxy bid.<sup>3</sup> However these bids came in so late—the last bid came in only 4 seconds before the end of the auction—that the losing bidders had no time to revise their bids, even if they wished to.

Note also that, before the last seconds of the auction, some bidders did wish to revise their bids, after being outbid by other bidders. Two of the bidders, including the winning bidder, bid more than once. The bidder with username *dglawrence* made the first bid, and later, with less than a minute until the end of the auction, raised his maximum by \$5,100. And the winning bidder, with username *tomcam*, placed his first proxy bid with just over three minutes to go, and then raised it by more than \$10,000 with just seconds to go.

That is, not only do bidders wish to bid late, they may wish to bid more than once. This, too, is not uncommon behavior. While most (human or artificial) bidders (62 percent) from the

sample represented in Figure 1 bid only once, many bidders increase their bid in the course of the auction. The average number of bids per bidder is 1.89.

So, we see that bidders are not using the eBay proxy bidding agent as eBay advises, to bid once, early in the auction. This is what has opened the door for third parties to offer their own bidding agents to eBay bidders. To understand what is going on, we turn next to consider why it is that bidders may wish to bid late.

### **III. Last-minute bidding and bidding wars**

There are risks in last-minute bidding. Because the time it takes to place a bid may vary considerably due to, for instance, internet congestion or connection times, last-minute bids have a positive probability of being lost. In a survey of 73 bidders who successfully bid at least once in the last minute of an eBay auction, 86 percent replied that it happened at least once to them that they started to make a bid, but the auction was closed before the bid was received (Roth and Ockenfels, forthcoming). Humans and artificial agents do not differ in this respect. The online sniping agent esnipe.com admits that it cannot make sure that all bids are actually placed: “We certainly wish we could, but there are too many factors beyond our control to guarantee that bids always get placed. While we have a very good track record of placed bids, network traffic and eBay response time can sometimes prevent a bid from being completed successfully. This is the nature of sniping” (<http://www.esnipe.com/faq.asp>, 2000). But while this danger creates an incentive not to bid too late, there are also incentives not to bid early in the auction, when there is still time for other bidders to react, to avoid a bidding war that will raise the final transaction price. In particular, we identify three distinct kinds of bidding wars: bidding wars with incremental bidders, with like-minded late bidders, and with uninformed bidders who look to others’ bids to determine the value of an item.<sup>4</sup>

#### *III.1 Bidding late to avoid bidding wars with incremental bidders*

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<sup>3</sup> The bid history reveals all but the highest proxy bid. The highest proxy bid is not recorded, since the final price is one bid increment (\$100 at this price level) above the second highest proxy bid.

<sup>4</sup> The following sections are based on Ockenfels and Roth (2001), who offer a game theoretic analysis of late and incremental bidding strategies, Roth and Ockenfels (forthcoming), who provide field evidence for strategic late

Last-minute bidding may be a best reply to incremental bidding. To see why, put yourself in the place of the bidder described earlier, who is willing to pay up to \$100 for an antique coin. Moreover, suppose that there is only one other potential bidder, and that you believe that this bidder is willing to pay more than you for the coin, say \$110. This other bidder, however, bids incrementally, that is, he starts with a bid well below his maximum willingness to pay and is then prepared to raise his proxy bid whenever he is outbid, as long as the price is below his willingness to pay. Last-minute bids can be a best response to this kind of incremental bidding because bidding very near the deadline of the auction would not give the incremental bidder sufficient time to respond to being outbid. By bidding at the last moment, you might win the auction at the incremental bidder's initial, low bid, even though the incremental bidder's willingness to pay exceeds your willingness to pay. As esnipe.com puts it: "A lot of people that bid on an item will actually bid again if they find they have been outbid, which can quickly leading to a bidding war. End result? Someone probably paid more than they had to for that item. By sniping, you can avoid bid wars." (<http://esnipe.com/faq.asp>).

By way of example, Figure 3 shows the bid history of an auction that ended on June 4, 2001 at 19:53:26 PDT. The history reveals that until 16:47 of the last day of the auction, just before the eventual high bidder *richardb2* submitted his bid, *oguzhan1* was the high bidder. Then, *richardb2* became the high bidder, at a bid (well below his proxy bid) of \$20,100, one increment over the then second highest proxy bid of \$20,000. With about five minutes left, bidder *adgatto* placed a proxy bid of \$25,095, and, finding that this was not a winning bid, raised his bid twice in the next few minutes, without, however, becoming the high bidder. It thus appears likely that if *richardb2* had bid later than *adgatto*, and too late for him to respond, he would have saved over two thousand dollars, since *adgatto* would likely have been satisfied to be the high bidder with his initial proxy bid.

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bidding, and Ariely, Ockenfels and Roth (2001), who focus on experimental and field evidence on the interaction between incremental and multiple bidding.



## eBay Bid History for

OVER! \$450,000 OF ANTIQUE PRINTS & WEBSITE! (Item # [1433842745](#))

Currently	\$27,600.00	First bid	\$5,000.00
Quantity	1	# of bids	30
Time left	Auction has ended.		
Started	May-25-01 19:53:26 PDT		
Ends	Jun-04-01 19:53:26 PDT		
Seller (Rating)	<a href="#">ajrule.vintage (585)</a> ★		

[View page with email addresses](#) (Accessible by Seller only) [Learn more.](#)

### Bidding History (Highest bids first)

User ID	Bid Amount	Date of Bid
<a href="#">richardb2 (430)</a> ★	\$27,600.00	Jun-04-01 16:47:52 PDT
<a href="#">adpatto (0)</a>	\$27,500.00	Jun-04-01 19:51:28 PDT
<a href="#">adpatto (0)</a>	\$27,000.00	Jun-04-01 19:49:46 PDT
<a href="#">adpatto (0)</a>	\$25,095.00	Jun-04-01 19:48:56 PDT
<a href="#">oguzhan1 (93)</a> ★	\$20,000.00	Jun-04-01 15:10:38 PDT

**Figure 3.** Late bidding as best response to incremental bidding

### III.2 Bidding late to avoid bidding wars with like-minded bidders

Bidding late can also be the best response to the late bidding strategies of like-minded bidders. As an example, suppose that you are willing to pay up to \$100 for an antique coin, and that there is only one other potential bidder who you believe has also a willingness to pay of about \$100. If both of you submit your value early, you will end up with a second highest submitted proxy bid of about \$100 implying a price of about \$100. Thus, regardless of whether you win or not, your earnings (calculated as your value minus the final price if you are the winner, and zero if you are the loser) would be close to zero.

Now consider a strategy that calls for a bidder to bid \$100 at the very last minute and not to bid earlier, unless the other bidder bids earlier. If the other bidder bids earlier, the strategy calls for a bidder to respond by promptly bidding his true value. If both bidders follow this strategy and mutually delay their bids until the last minute, both bidders have positive expected profits, because there is a positive probability that one of the last-minute bids will not be successfully transmitted, in which case the winner only has to pay the (small) minimum bid. But if a bidder deviates from this strategy and bids early, his expected earnings are (approximately) zero

because of the early price war triggered by the early bid. Thus following the last-minute strategy, expected bidder profits will be higher and seller revenue lower than when everyone bids true values early (see Ockenfels and Roth, 2001, for a game theoretic model and formal proof that this can constitute equilibrium behavior<sup>5</sup>).

### *III.3 Bidding late to protect information in auctions with interdependent values*

There are additional strategic reasons to bid late in auctions with interdependent values ('common value auctions'). As an example, suppose you are a dealer of antique coins who can distinguish whether a coin is genuine or worthless. Suppose you identified an antique coin auctioned in eBay as genuine and that your maximum willingness to pay is \$100. Another potential bidder, however, is not an expert and thus cannot tell whether the coin is genuine or worthless, but values a genuine coin higher than you, say \$110. What should you do?

When values are interdependent as in this example, the bids of others may carry valuable information about the item's value that may provoke a bidder to increase his willingness to pay. This creates incentives to bid late, because by bidding late, less informed bidders can incorporate into their bids the information they have gathered from the earlier bids of others, and experts can avoid giving information to others through their own early bids. Specifically, in the scenario described above, if the minimum bid is positive and the probability that the coin is worthless is sufficiently high, the uninformed bidder should not bid unless the expert submitted a bid earlier and thus signaled that the coin is genuine. Bidding without such a signal from the expert would run the risk of losing money by paying the minimum price for a worthless coin. Such conditional bidding behavior of uninformed bidders creates in turn an incentive for experts to submit the bid for a genuine item very late in order to, as *esnipe.com* puts it, "prevent other bidders from cashing in on their expertise". Last-minute bids do not leave sufficient time to uninformed bidders to respond to and outbid experts' bids (see Ockenfels and Roth, 2001, for a game theoretic model).

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<sup>5</sup> The fact that late bidding can constitute an equilibrium behavior means that, even if bidders initially learn to bid late as a best response to the behavior of inexperienced bidders, there is no reason to expect it to be a transient phenomenon that will disappear as bidders become more experienced.

### eBay Bid History for

ANTIQUE GERMAN NIAGARA FALLS WIRE BASKET NR (Item #463085061)

Currently	\$9.99	First bid	\$9.99
Quantity	1	# of bids	1
Time left	Auction has ended.		
Started	Oct-08-00 21:10:39 PDT		
Ends	Oct-18-00 21:10:39 PDT		
Seller (Rating)			

#### Bidding History (Highest bids first)

User ID	Bid Amount	Date of Bid
<a href="#">lmuseum@city.niagarafalls.on.ca</a> (114) ★	\$9.99	Oct-18-00 21:10:34 PDT

Remember that earlier bids of the same amount take precedence.

**Figure 4.** Late bidding to protect information

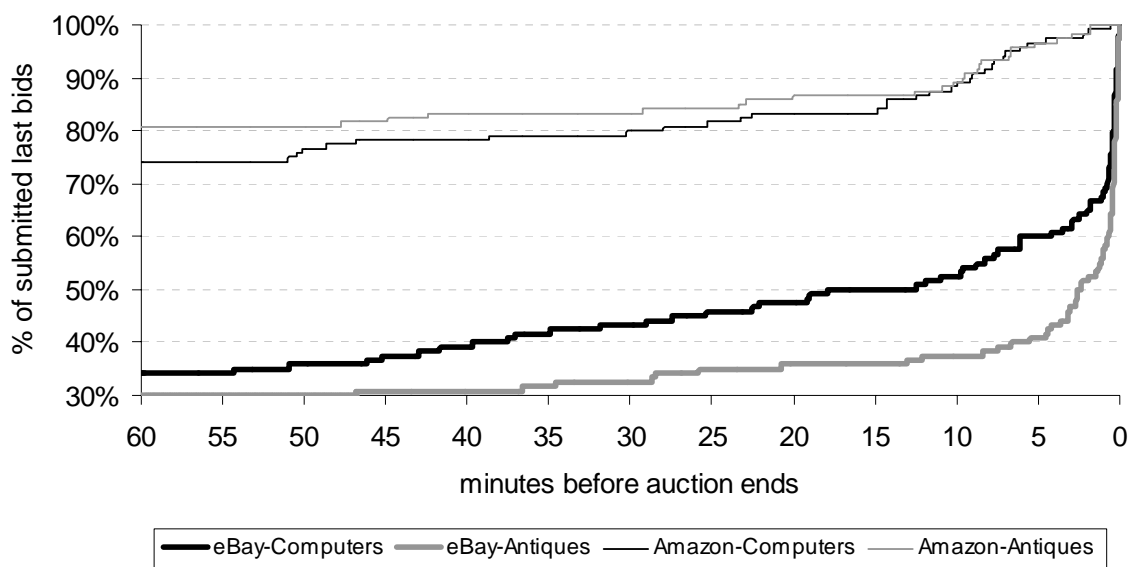
As an illustration, Figure 4 displays the bid history of a completed auction that gives reason to speculate that we might be seeing an expert protecting information. The auction had only one bid, placed so late –five seconds before the deadline– that nobody could respond. This is an antiques auction, and antiques might reasonably be expected to have significant scope for asymmetric information among bidders as to the authenticity and value of items. The bidder’s feedback number of 114 indicates that the bidder is familiar with the rules and bidding strategies in eBay auctions, since the bidder must have completed at least 114 eBay auctions as a seller or a high bidder. And finally, the bidder’s ID is the email address of Lundy’s Lane Historical Museum in the City of Niagara Falls, Canada, suggesting that the bidder is indeed likely to have special expertise on antiques related to Niagara Falls, such as the one in this auction.

#### *III.4 Strategic versus non-strategic hypotheses for late bidding*

There are other, non-strategic reasons for late bidding, including procrastination, use of search engines that make it easy to find auctions about to end, endowment effects, or management of bidding in multiple auctions in which similar objects may be offered. In a recent paper (Roth and Ockenfels, forthcoming), we considered the extent to which strategic and non-strategic reasons cause late bidding with the help of bid history data from eBay and Amazon. Amazon auctions, while operating under otherwise similar rules as eBay, are automatically extended if necessary past the scheduled end time until ten minutes have passed without a bid. While the

risks of last-minute bidding remain, the strategic advantages of last-minute bidding are eliminated or severely attenuated in Amazon-style auctions. That is, a bidder who waits to bid until the last seconds of the auction still runs the risk that his bid will not be successfully transmitted in time. But if his bid is successfully transmitted, the auction will be extended for ten minutes, so that, no matter how late the bid was placed, other bidders will have time to respond. Thus on Amazon, an attentive incremental bidder, for example, can respond whenever a bid is placed. The non-strategic motives for late bidding, on the other hand, should be relatively unaffected by the difference in closing rules between eBay and Amazon. Thus a comparison of bidding patterns between eBay and Amazon auctions offers the possibility of discerning whether the strategic factors we have been discussing do indeed play a significant role in causing bidders to bid late.

Figure 5 shows the empirical cumulative probability distributions of the timing of the last bid in each auction for a sample of 480 eBay and Amazon auctions of antiques and computers with a total of 2279 bidders.



**Figure 5.** Cumulative distributions over time of auctions' last bids (Roth and Ockenfels, 2000)<sup>6</sup>

The figure shows that there is significantly more late bidding on eBay than on Amazon. For instance, 40 percent of eBay-Computers auctions and 59 percent of eBay-Antiques auctions in our sample have last bids in the last 5 minutes, as compared to about 3 percent of both Amazon-Computers and Amazon-Antiques auctions that have last bids in the last five minutes before the initially scheduled deadline or later. Further analyses reveal that the impact of the bidders' feedback numbers on late bidding is significantly positive in eBay and negative in Amazon. This suggests that more experienced bidders on eBay bid later than less experienced bidders, while experience in Amazon has the opposite effect. Figure 5 also reveals that significantly more late bidding can be found in antiques auctions than in computer auctions on eBay, suggesting that the expertise effect described in Section III.3 is reflected in the timing of bids.

Both the difference in late bidding between eBay and Amazon auctions, and the different amount of late bidding between eBay auctions of computers and antiques, suggest that late bidding arises in large part from the rational response of the bidders to the strategic

<sup>6</sup> Since Amazon auctions cannot close until 10 bidless minutes have passed, we calculated a 'hypothetical' deadline for Amazon auctions for the comparison in Figure 5. This hypothetical deadline relevant to a given bid is defined as the current actual deadline at the instant before the bid is placed; i.e. it is the time the auction would have ended if the current bid and any subsequent bids had not been submitted. Note that this presentation may lead us to

environment.<sup>7</sup> It is worth noting in this context that Amazon auctions have attracted much less interest from third party suppliers of sniping software. Most of the sniping agents seem to be aimed squarely at eBay, and many (including esnipe) seem to have eBay as their only target.

#### **IV. Incremental bidding and how it interacts with late bidding**

In the data set of Ockenfels and Roth (2001), 38 percent of the bidders bid at least twice. Among these bidders, the large majority submit a new bid after being outbid. In particular, 53 percent of the last bids of incremental bidders are placed after the previous bid was automatically outbid by eBay's proxy bidding agent (i.e., by another bidder's proxy that was submitted earlier in the auction), 34 percent are placed after the previous bid was outbid by a newly submitted proxy bid of another (human or artificial) bidder, and only 13 percent are placed by the current high bidder (so that the current price is not changed).

One way to explain the multiple bid phenomenon without positing inexperience or irrationality on the part of the bidders is to note that bidders sometimes can get information from others' bids that causes them to revise their willingness to pay in auctions with interdependent values (see Section III.3).<sup>8</sup> But incremental bidding might also be caused by naïve, inexperienced bidders, who mistakenly treat the eBay auctions like English first price auctions in which the high bidder pays his maximum bid.<sup>9</sup> But regardless of the causes for incremental bidding, incremental bidders are likely to drive last-minute bidding. First, as explained in Section III, last-minute bidding may be the best response of sophisticated (one-bid) bidders to incremental bidding, regardless of whether incremental bids are caused by unsophisticated 'first price-bidding' or by sophisticated information updating over time in auctions with interdependent

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overestimate the extent to which Amazon-bidders bid late which would only strengthen our comparative results (see Roth and Ockenfels, 2000).

<sup>7</sup> Experiments of Ariely et al. (2001) reproduce the private-goods effect in a laboratory setting in which the only difference between auctions is the ending rule. The experiment thus controls for differences other than the closing rule that might affect behavior on Amazon and eBay, such as the number of auctions being conducted at any time.

<sup>8</sup> Ockenfels and Roth (2001) prove that there can also exist equilibria in auctions with independent values at which bidders may bid both early and very late. Other strategic reasons for multiple bidding include bidding below a secret reservation price, since auctions in which the high bid is less than the reserve price sometimes lead to post-sale negotiations, so that there is an incentive for a bidder not to bid against himself if he is the current high bidder for fear of going over the reservation price and having to pay it in full.

<sup>9</sup> Other non-strategic reasons for multiple bidding include various psychological reasons why a bidder's maximum willingness to pay increases over time.

values. Second, incremental bidders themselves may bid late, because bidders who increase their bids after being outbid have an incentive to come back to the auction close to the deadline to check whether they are outbid, or just because incremental bidding takes more time than placing a single bid. Indeed, a substantial share of both, one-bid bidders (12 percent) and multiple bidders (16 percent) bid as late as in the last ten minutes of the eBay auctions (Ockenfels and Roth, 2001). However, the data also reveals that among these late bidders, one-bid bidders submit their bid later than incremental bidders.

Thus, many incremental bidders bid late, but one-bid bidders tend to bid even later. Moreover, the data indicates that incremental bidding significantly diminishes with experience (as measured by the bidders' feedback numbers), while last-minute bidding increases with experience. Overall, the analysis of multiple bids supports the hypothesis that last-minute bidding arises at least in part as a response by sophisticated bidders to unsophisticated incremental bidding.

## **V. Conclusions**

Whether the timing of bids matters depends on the rules of the game. Artificial last-minute bidding agents like *esnipe.com* may support human bidders in eBay auctions, but they would hardly help on Amazon, where the closing rule removes or greatly attenuates the incentives to snipe. By the same token, human bidders on Amazon have more reason to make use of the proxy bidding agent provided by the auction houses than bidders on eBay, where the fixed deadline may create incentives to submit the bid late, depending on other (human or artificial) bidders' behavior. So how well different kinds of software agents perform depends on the rules of the game.

As bidders learn from experience how to better take into account the incentives that the rules of the market create, their demand for helpful software agents grows. Changes in bidder behavior, and in the availability of bidding agents, both also change the strategic environment, and the incentives of the other market participants. For example, if sniping and sniping agents become even more widespread on eBay than they are today, eBay would be gradually transformed into a sealed bid second price auction. If a large part of the bidding action were taking place on third party sites like *esnipe*, eBay would face a number of choices. One would

be to recapture the sniping market by offering a sniping option on eBay itself. (Under this option, last minute bids submitted in advance directly to eBay could all be counted at the same time, immediately after the auction close, thus giving bidders certainty both that their bids would be successfully transmitted, and that there would be no time for other bidders to react.) Of course, if all bidders used this option, the auction would be precisely a sealed bid auction. eBay, and sellers who list items for sale on eBay, might prefer not to encourage this development (for example if they believe that bidders are likely to bid more in auctions in which they can form some estimates of how much other bidders value the item for sale.) In such a case, eBay's managers could explore other options, such as changing the ending rule of the auction (but this in turn raises other design issues).

In summary, the problems facing market designers involve anticipating how participants will respond to the market rules. Internet markets make the adoption of software agents one possible part of this response, and the game-theoretic analysis of the market rules helps anticipate and understand the incentives that drive these responses. Because artificial agents have to be adopted by human agents, and have to interact with human as well as artificial agents under the rules of the market, the task of the artificial agent designer is also closely related to the strategic analysis facing human agents. Thus there is going to be a lot of room for market designers and agent designers to talk to and learn from each other.<sup>10</sup>

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<sup>10</sup> In this connection, see also Roth and Peranson (1999) which describes the design of the "smart market" used to match about 20,000 American physicians a year to their first jobs. In that market, each job applicant, and each employer, submits a preference ordering over the agents on the other side of the market (as well as some other information) and then the market itself is conducted by artificial agents acting on behalf of each applicant and employer.



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