COMPUTER JOTTO AND CRASH

LEONARD GORDON
Tucson, Arizona

The August 1996 article "Playing Jotto Against a Computer" discusses the game of Jotto as played by a commercial computer program. Toward the end of the article, the authors suggest a "better" (minimax) value of play. I agree that their method is too difficult to implement, but I also believe that it is based on a weak premise and would be useless even if implemented. There can be no compleat strategy to Jotto. Guessing your opponent’s word is a matter of bookkeeping plus a little luck. Since the computer is a better bookkeeper and knows its vocabulary better than a human opponent, its best strategy is thoughtful random play.

To test my opinions, I wrote a computer program. (As always happens, I got carried away and wrote several.) My programs do not play a full game; they only guess an opponent’s target word. While testing my programs, I noticed certain weaknesses in the logic (places where a clever opponent could force the computer into an excessively long search) and introduced a few remedies; after that the programs seemed to play pretty well. (How well? The reader must decide from reading this article, or from trying out my programs himself, as offered in the November 1996 Colloquy.) After Jotto, I wrote a program for a form of Giotto (14th-century Italian painter) best known to Word Ways readers as Crash. Both programs use five-letter Official Scrabble Players Dictionary words.

THE JOTTO ALGORITHM

My algorithm accomplishes the same thing as the one described in the August article. Establish a linear array, V(L), for L = 1 to 26. Add to it after every word guessed. For example, if the first guess is CRWTH, we mark V(3) = 1, V(18) = 1, V(23) = 1, V(20) = 1, V(8) = 1. Say the second word is ORGAN. We now add V(15) = 5, V(18) = 1 + 5 = 7, V(7) = 6, V(1) = 1, V(14) = 6. If our third guess is STARE, we add V(19) = 36, V(20) = 1 + 36 = 37, etc. At the 12th guess we add 362,797,056 (6 to the eleventh power) per letter.

From reports of the number of hits, we compile HSUM = H1 + 6H2 + 36H3 + 216H4 + ..., where H(i) is the number of hits scored by the ith guess word. The first few guesses by the computer may be preprogrammed (independent of the hit numbers); however we eventually get to the point where we want to calculate the value of each potential next guess word using VAL = V(L1) + V(L2) + V(L3) + V(L4) + V(L5). The program runs down the stored list and accepts the first word for which VAL(N) = HSUM (N-1).
There are two basic ways to use this algorithm. In the first, the program makes a guess more or less at random and then proceeds down the VAL = HSUM path. In the second, the program uses four or five presel ected guess words, records the hits, but makes no use of this information until it goes to make the fifth or sixth guess. In either procedure, a few words are placed at the head of the main list for various reasons. The rest of the list is scrambled.

A major weakness of Jotto is that anagrams are indistinguishable from one another. Once an anagram of the target is found, there is no alternative to blindly guessing other anagrams until the opponent says "that's it". I mitigate the problem somewhat by placing one member of each large set of anagrams at the head of the list. The largest OSPD set is AEPRS with eleven members. If one of its members (an anagram of the target) is hit with the fifth guess, we can expect to hit the target by the tenth. The worst case will be 15 guesses. The locations of the anagrams in the list are scrambled after each game.

Words containing AERS and one other letter are the worst targets in Jotto. Table 1 lists 93 of them; the fifth letter can be every one except Q. Should the program start guessing with BREAD 3, CARES 4, it can get trapped in a long path something like FEARS 4, RAGES 4, SHEAR 4, ARISE 4, RAJES 4, ... RAZES 5. This is where starting with four or five non-overlapping words comes into its own. Guessing with a bunch of consonants early on helps avoid the 4-4-4 trap. Both of my Jotto programs start with a word list that was scrambled when first made. In the pure VAL = HSUM method, this list is further scrambled each time it is read in. This helps prevent an opponent from taking advantage of the AERS? and similar weaknesses. (The programs go through a few other shenanigans not worth discussing.)

The article "A New Look at the Jotto Problem" in the November issue abstracts a very extensive list of five-word starter combos for Jotto. These combos were found by an iterative process. They can not be developed in the course of a Jotto game, as some may imply from the article. None use all OSPD words, but four non-overlapping words (all OSPD) serve well enough for our game. Table 2 gives a set of five-word combos with OSPD words, but only the first four words are non-overlapping (use 20 different letters) and have one vowel per word; the fifth word contains the remaining two vowels and has one consonant in common with the others. These words are used as follows: Choose a combo at random from several included in the program. Take the first three members as guesses. If they make five hits on the target, skip the fourth member and continue the search with the VAL = HSUM method. Otherwise, take the fourth word as a guess and then continue with VAL = HSUM. But, if there are less than four hits with the first four words, take the reserve word as the fifth guess. The seven-guess finding for KALIF (below) is a perfect illustration of its use.
For target words chosen at random, the pure VAL = HSUM and the present combo methods do about equally well, with an average of 8.2 guesses per game. I prefer the second method for the reason given above. Here are sample games using the second method:

<table>
<thead>
<tr>
<th>target</th>
<th>guesses needed</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUITE</td>
<td>8, 5, 8, 8, 7, 8, 6, 9, 8, 6</td>
<td>7.3</td>
</tr>
<tr>
<td>EMPTY</td>
<td>11, 9, 8, 8, 7, 6, 8, 7, 7, 8</td>
<td>7.9</td>
</tr>
<tr>
<td>RAZES</td>
<td>9, 6, 7, 7, 9, 8, 8, 7, 9, 9</td>
<td>7.9</td>
</tr>
<tr>
<td>SCHAIV</td>
<td>8, 8, 8, 8, 8, 9, 7, 8, 8, 9</td>
<td>8.1</td>
</tr>
<tr>
<td>KALIF</td>
<td>9, 8, 8, 7, 9,10, 7,10, 9, 8</td>
<td>8.5</td>
</tr>
<tr>
<td>ENVOI</td>
<td>7, 8, 8, 9, 9, 8, 7, 8, 8, 9</td>
<td>9.1</td>
</tr>
<tr>
<td>ESTOP</td>
<td>6, 9, 7,11, 9, 6, 8, 8, 9,10</td>
<td>9.1</td>
</tr>
<tr>
<td>BREAD</td>
<td>9,10,12, 8, 8, 6, 8,10,12,10</td>
<td>9.3</td>
</tr>
</tbody>
</table>

gawks 1, vetch 1, fjord 2, plumb 1, torus 1, mowed 2, acold 2, pared 4, debar 5, ardeb 5, beard 5, bread 5
gambs 1, wench 1, fjord 0, klutz 1, privy 2, spiel 2, inapt 2, pubic 1, lying 1, peaky 3, empty 5
dwarf 2, blitz 1, jocks 1, squee 2, tears 4, arise 4, laser 4, sabre 4, razes 5
bortz 0, vangs 1, fjeld 2, whump 0, kylix 3, yelks 2, kalif 5
rewax 1, blitz 0, fjord 0, gucks 2, nymph 1, quays 2, vangs 3, nevus 2, schav 5
waltz 1, gecks 1, fjord 0, squib 3, quite 5

THE CRASH ALGORITHM

Books by Tony Augarde, Gyles Brandreth, and David Parlett all mention (usually only briefly) various versions of Giotto. The game that I like best is often called Crash; that title was used by Dave Silverman in an August 1969 Word Ways Kickshaws. The best description of the game is in Peter Newby’s Pears Word Games which calls it Words. There is also a boxed version called Words Worth.

After describing Words, Peter Newby says "Jotto is logical deduction for the hard of thinking". Words is the better game, but it is not that much different from Jotto. In Words (= Crash), a player reports a hit if the guess word has a letter corresponding to one in the same position in the target; for example, BearD scores two hits on BreaD. Newby's procedure for guessing the target can be improved upon. The algorithm is identical to that described above for Jotto except we keep a separate score for each letter position.

Newby refers to E as the most commonly used letter in the alphabet. For our purposes this is not correct. Let’s look at the data. Table 3 lists occurrences of letters in various positions for five-letter OSPD words. For isograms, E, S, and A are about equally frequent. I didn’t use these frequencies for choosing starter words for Jotto, but I did
use them for playing Crash with isograms (discussed in the next section). For playing Crash with the full OSPD list, we must consider frequencies in each of the five positions separately. E is hardly used in first position and S is hardly used in second. Let's use those facts to establish starting words for Crash.

In each of the following combos, there are five different letters in each position (column). The words are chosen to use the most frequent letters possible. The left combo is almost perfect in that respect. I am not sure that a statistical approach is best, but I use these in Crash for lack of any better idea. Of the 8184 OSPD words, only 135 do not get hit by the first combo. The other combos are not quite as good but serve to add variety and concealment to the guessing. If we add ARENA, INDOL and PLUSH to the left combo, no OSPD word gets by, but using more than five words in a starter set leads to diminishing returns.

<table>
<thead>
<tr>
<th>peris</th>
<th>tunas</th>
<th>brats</th>
<th>delis</th>
</tr>
</thead>
<tbody>
<tr>
<td>cooed</td>
<td>cried</td>
<td>toned</td>
<td>boned</td>
</tr>
<tr>
<td>talar</td>
<td>salty</td>
<td>saint</td>
<td>carat</td>
</tr>
<tr>
<td>suite</td>
<td>aerie</td>
<td>curie</td>
<td>slaty</td>
</tr>
<tr>
<td>bialy</td>
<td>boart</td>
<td>delay</td>
<td>thine</td>
</tr>
</tbody>
</table>

Like Jotto, Crash has a weakness. There are 134 OSPD words of the form ?A?ES, given in Table 4. The fix for Crash is different than for Jotto. Here we have to rely on catching the problem early and jumping out of the starter set. Whenever there are three or more hits in the starter words, the program switches to the VAL = HSUM sequence. Note that ?A?ES will always be detected in three guesses with the above starts. Here are some test reports. The average number of guesses seems to be about 10.

<table>
<thead>
<tr>
<th>target</th>
<th>guesses</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>WALTZ</td>
<td>5, 6, 8, 7, 10, 8, 7, 9, 6, 6</td>
<td>7.2</td>
</tr>
<tr>
<td>QUITE</td>
<td>8, 6, 5, 7, 11, 6, 7, 7, 8, 8</td>
<td>7.3</td>
</tr>
<tr>
<td>BREAD</td>
<td>8, 9, 7, 9, 7, 5, 7, 9, 6, 6</td>
<td>7.3</td>
</tr>
<tr>
<td>KALIF</td>
<td>8, 7, 8, 8, 7, 10, 6, 8, 9, 6</td>
<td>7.9</td>
</tr>
<tr>
<td>EMPTY</td>
<td>8, 10, 10, 7, 9, 10, 10, 9, 10, 9</td>
<td>9.2</td>
</tr>
<tr>
<td>RAZES</td>
<td>12, 8, 11, 8, 12, 13, 7, 6, 9, 13</td>
<td>9.9</td>
</tr>
<tr>
<td>DESEx</td>
<td>9, 11, 11, 9, 10, 12, 10, 10, 8, 11</td>
<td>10.1</td>
</tr>
<tr>
<td>SCHAV</td>
<td>11, 10, 8, 9, 9, 12, 11, 11, 10, 13</td>
<td>10.4</td>
</tr>
<tr>
<td>HEIGH</td>
<td>11, 12, 10, 9, 11, 11, 8, 11, 12, 10</td>
<td>10.5</td>
</tr>
<tr>
<td>VROOM</td>
<td>13, 7, 9, 11, 10, 11, 10, 12, 10, 13</td>
<td>10.6</td>
</tr>
<tr>
<td>QUIAFF</td>
<td>11, 12, 11, 9, 10, 11, 11, 12, 9, 12</td>
<td>10.8</td>
</tr>
<tr>
<td>ESTOP</td>
<td>10, 12, 10, 10, 13, 12, 10, 13, 10, 9</td>
<td>10.9</td>
</tr>
<tr>
<td>ENVOI</td>
<td>10, 11, 11, 12, 12, 11, 10, 11, 12</td>
<td>11.0</td>
</tr>
<tr>
<td>JUJUS</td>
<td>13, 13, 13, 13, 10, 13, 12, 10, 11, 10</td>
<td>11.8</td>
</tr>
</tbody>
</table>

peris 0, cooed 1, talar 1, suite 0, bialy 1, cabby 0, liner 0, bread 5 delis 0, boned 0, carat 0, slaty 1, thine 2, stone 1, shill 1, alike 2,
plink 1, unite 3, quite 5
brats 1, toned 1, saint 1, fates 3, cafes 3, eaves 3, wames 3, mares 3,
rapes 4, raxes 4, rages 4, races 4, razes 5
delis 0, boned 0, carat 0, slaty 0, thine 0, uteri 0, achoo 1, amuck 0,
oxbow 1, mucor 1, gipon 1, proof 3, vroom 5
peris 0, coed 0, talar 0, suite 1, bialy 1, skull 0, disme 0, wrath 1,
quasi 3, quart 3, quack 3, quaff 5

A fascinating aspect of playing with either the Jotto or the Crash programs is to watch how they sometimes find a target without having made many early hits. ENVOI and ESTOP do not crash with any of the above starter combos. Here are some guessing sequences that find them:

peris 0, coed 0, talar 0, suite 0, bialy 0, glyph 0, intro 1, uteri 1,
eni 3, envoi 5
tunas 0, cried 0, salty 0, aerie 0, boart 0, rheum 0, lymph 0, oxbow 1,
indol 2, nicol 1, envoi 5
delis 0, boned 0, carat 0, slaty 0, thine 0, octyl 0, edema 1, wreck 0,
hydra 0, eikon 2, ephor 2, envoi 5
delis 0, boned 0, carat 0, slaty 0, thine 0, fresh 0, oxbow 1, extra 0,
estop 5
delis 0, boned 0, carat 0, slaty 0, thine 0, hyrda 0, fresh 0, achoo 1,
awful 0, oxbow 1, mucor 1, piton 2, estop 5

THE ISOGRAM CRASH ALGORITHM

Here are starter combos for Isogram Crash (I-Crash). 88 words are not hit by the first combo. (The following eight words hit all of the isograms: CRATE, DELAY, PIORD, PURIN, SAINT, TONER, ALTOS, THECA.)

<table>
<thead>
<tr>
<th></th>
<th>dairy</th>
<th>pries</th>
</tr>
</thead>
<tbody>
<tr>
<td>bolas</td>
<td>cions</td>
<td>tined</td>
</tr>
<tr>
<td>saint</td>
<td>boite</td>
<td>saint</td>
</tr>
<tr>
<td>curie</td>
<td>train</td>
<td>curie</td>
</tr>
<tr>
<td>peaty</td>
<td>deray</td>
<td>peaty</td>
</tr>
</tbody>
</table>

Here are results of a few tests:

<table>
<thead>
<tr>
<th>target</th>
<th>guesses</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>BREAD</td>
<td>5, 6, 8, 5, 8, 8, 8, 6, 8, 7</td>
<td>6.9</td>
</tr>
<tr>
<td>QUITE</td>
<td>10, 8, 6, 5, 10, 7, 7, 8, 8, 8</td>
<td>7.7</td>
</tr>
<tr>
<td>EMPTY</td>
<td>8,10,10,10,10, 9,10, 9, 7,11</td>
<td>9.4</td>
</tr>
<tr>
<td>KALIF</td>
<td>9,11, 9,10, 8, 8,12,10,10, 8</td>
<td>9.5</td>
</tr>
<tr>
<td>RAZES</td>
<td>11,10,10, 8, 8, 7,10,11,10,12</td>
<td>9.7</td>
</tr>
<tr>
<td>SCHAV</td>
<td>9, 8, 9,11,10, 9,11,10,11,10</td>
<td>9.8</td>
</tr>
</tbody>
</table>
COMPARING THE THREE GAMES

Here is a very brief comparison of the three guessing games. About all we can say here is that Jotto is a bit faster than Crash. They are two different games so this is not important. BREAD is an easy target for Crash but gets fouled by the anagram problem in Jotto. ESTOP also contains frequently used letters but gets fouled in the anagram trap. It is a difficult target in both Jotto and Crash, but for different reasons.

<table>
<thead>
<tr>
<th></th>
<th>JOTTO</th>
<th></th>
<th>CRASH</th>
<th></th>
<th>I-CRASH</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>avg</td>
<td>range</td>
<td>avg</td>
<td>range</td>
<td>avg</td>
<td>range</td>
</tr>
<tr>
<td>BREAD</td>
<td>9.3</td>
<td>6 to 12</td>
<td>7.3</td>
<td>5 to 9</td>
<td>6.9</td>
<td>5 to 8</td>
</tr>
<tr>
<td>EMPTY</td>
<td>7.9</td>
<td>6 to 11</td>
<td>9.2</td>
<td>7 to 10</td>
<td>9.4</td>
<td>7 to 11</td>
</tr>
<tr>
<td>KALIF</td>
<td>8.5</td>
<td>7 to 10</td>
<td>7.9</td>
<td>6 to 10</td>
<td>9.5</td>
<td>8 to 12</td>
</tr>
<tr>
<td>QUITE</td>
<td>7.3</td>
<td>6 to 9</td>
<td>7.3</td>
<td>5 to 11</td>
<td>7.7</td>
<td>5 to 10</td>
</tr>
<tr>
<td>RAZES</td>
<td>7.9</td>
<td>6 to 9</td>
<td>9.9</td>
<td>6 to 13</td>
<td>9.7</td>
<td>7 to 12</td>
</tr>
<tr>
<td>SCHAV</td>
<td>8.1</td>
<td>7 to 9</td>
<td>10.4</td>
<td>8 to 13</td>
<td>9.8</td>
<td>8 to 11</td>
</tr>
<tr>
<td>ESTOP</td>
<td>9.1</td>
<td>6 to 11</td>
<td>10.9</td>
<td>9 to 13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENVOI</td>
<td>9.1</td>
<td>7 to 9</td>
<td>11.0</td>
<td>10 to 12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GENERAL OBSERVATIONS

A Giotto-style commercial game called Mastermind was popular in 1975. It used six different colored pegs to define four-peg "words". Repeated colors in the target was allowed. Later, a five-peg version using eight colors was produced. Guessing was a combination of Jotto and Crash rules. Mastermind can be played with words instead of colored pegs. For example, if the target is STAIR and the guess is SOUTH, the report would be "one hit (S) and one letter out of place (T)". If the guess were SOUSE, the report would be "one hit" because the S in STAIR is only counted once. If the guess were TARRY, the response would be "three letters out of place". Only one R is counted. This game would probably be best with isograms to avoid the complicated rules. I may program this game in the future. One of the above mentioned books describes Jotto as "Word-Mastermind".

Two players can use my one-sided computer programs in a competitive game as follows: Player A picks a target and asks Player B to guess it. At the same time, Player A has the computer guess it. Player A scores the number of guesses the computer needed plus or minus the difference between the number of guesses Player B needed compared to the computer. This introduces a curious aspect to Jotto or Crash. Most players would have a tendency to pick obscure words for their opponent. The computer does well with these words. On the other hand, if a player picks one of the words (discussed above) which are tough on the computer, his human opponent might guess it easily.

I used the OSPD for this study mainly because it was available on disk. I would have preferred to use Merriam-Webster's 10th Collegiate, because the OSPD is too inclusive for games (including Scrabble). For
logology (or Scrabble tricks), we must use the largest database which is both available and manageable. Game playing is different. Giotto games with six-letter words should be interesting, but here too I would prefer to limit the vocabulary to 10th Collegiate.

**TABLE 1**

BARES baser bears braes saber sabre ACRES escar cares carse races scare serac DARES dears raised reads FARES fears safer AGERS gears rages sager sarge HARES hears rhews share shear ARISE raise serai RAJES ASKER eskar rakes saker ARLES earls lares laser lears railes reals seral MARES marse maser reams smear EARNS nares nears saner snare AROSE APERS asper pares parse pearse prase presa rapes reaps spare spear AURES urase ureas ursae AVERS raves saver WARES wears resaw sawer sewer sware swear RAXES EYRAS resay sayer years RAZES

**TABLE 3**

<table>
<thead>
<tr>
<th>ISOGRAMS</th>
<th>Q 42 9 6 0 0 57 Q 51</th>
<th>ALL 5-LETTER WORDS</th>
<th>11 8 0 0 70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q 85</td>
<td>J 0 106 J 126</td>
<td>14 75 59 14 203</td>
<td></td>
</tr>
<tr>
<td>Z 30</td>
<td>12 45 28 10 125 X 12</td>
<td>40 85 7 41 185</td>
<td></td>
</tr>
<tr>
<td>X 7</td>
<td>28 65 5 31 136 Z 41</td>
<td>14 75 59 14 203</td>
<td></td>
</tr>
<tr>
<td>V 113</td>
<td>20 120 57 2 312 V 157</td>
<td>38 160 91 2 448</td>
<td></td>
</tr>
<tr>
<td>F 314</td>
<td>8 49 59 20 440 W 285</td>
<td>96 149 87 39 656</td>
<td></td>
</tr>
<tr>
<td>W 218</td>
<td>58 119 70 28 493 F 414</td>
<td>14 120 145 49 742</td>
<td></td>
</tr>
<tr>
<td>K 102</td>
<td>24 106 223 131 586 K 180</td>
<td>52 129 295 174 830</td>
<td></td>
</tr>
<tr>
<td>B 389</td>
<td>25 123 65 20 622 B 566</td>
<td>50 200 130 31 977</td>
<td></td>
</tr>
<tr>
<td>G 267</td>
<td>21 139 170 74 671 G 389</td>
<td>46 225 253 83 996</td>
<td></td>
</tr>
<tr>
<td>Y 66</td>
<td>111 73 45 489 784 H 319</td>
<td>360 64 126 243 1112</td>
<td></td>
</tr>
<tr>
<td>H 222</td>
<td>269 47 96 182 816 M 419</td>
<td>114 319 255 119 1226</td>
<td></td>
</tr>
<tr>
<td>M 281</td>
<td>74 208 171 88 822 Y 81 153 114 59 831 1238</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P 374</td>
<td>99 140 157 85 855 P 531 166 229 259 113 1278</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C 456</td>
<td>80 183 194 72 985 C 639 118 249 276 93 1375</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D 289</td>
<td>31 145 195 431 1091 U 108 748 426 240 25 1547</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U 83</td>
<td>501 330 179 20 1113 D 424 56 259 291 565 1595</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| N 107     | 149 423 377 264 1320 N 176 232 591 506 347 1852 |
| T 344     | 99 253 369 351 1416 T 527 165 404 592 459 2147 |
| L 266     | 347 341 292 195 1441 L 380 488 555 516 336 2275 |
| O 122     | 822 365 234 113 1656 I 112 908 716 544 121 2401 |
| I 68      | 611 541 408 62 1690 O 176 1255 645 417 194 2687 |
| R 242     | 444 565 306 328 1885 R 388 618 751 447 505 2709 |

| A 269     | 968 617 391 156 2401 A 474 1396 823 611 334 3638 |
| S 562     | 36 127 199 1647 2571 E 188 999 548 1635 897 4267 |
| E 84      | 553 261 1105 603 2606 S 1021 61 323 334 2569 4308 |
| black vents fjord whump zingy qx | blawn kempt fjord vugh s cylix qz |
| blawn kempt fjord vugh s zincy qx | brawn fjeld compt vugh s kylig qz |
| brawn fjeld compt vugh s zinky qx | champ fjeld bortz swung kylig qv |
| gambs wench fjord klutz privy qx | gambs wench fjord klutz pyxis qv |
| gawks fjeld bortz chump vinyl qx | gawks fjeld bortz chump vying qx |
| gawks fjeld bortz munch privy qx | gawks fjeld bortz munch pyxis qv |
| gawks vetch fjord plumb zingy qx | gawks vetch fjord plumb zincy qx |
| gnaws fjeld bortz chump kylig qv | gawks vetch fjord plumb zinky qx |
| gnaws vetch fjord plumb zinky qx | gawks vetch fjord plumb zingy qx |
| snack fjeld bortz whump vying qx | gnaws vetch fjord plumb kylig qz |
| swamp fjeld bortz chunk vying qx | gnaws vetch fjord plumb zinky qx |
| swang vetch fjord plumb kylig qz | swang vetch fjord plumb zinky qx |
| swank fjeld bortz chump vying qx | swang vetch fjord plumb zingy qx |
| twang fjeld crumb qphs kylig vz  | twang fjeld crumb qphs zinky vz  |
| vamps bench fjord klutz wingy qx | vamps bench fjord klutz wingy qz |
| vamps fjeld botch wrung kylig qz | vamps fjeld botch wrung zinky qz |
| vamps fjeld butch grown kylig qz | vamps fjeld butch grown zinky qx |
| vamps fjeld butch wrong kylig qz | vamps fjeld butch wrong zinky qz |
| vamps wench fjord klutz bigly qx | vamps wench fjord klutz bigly qz |
| vangs fjeld bortz chump kylig qw | vangs fjeld bortz whump cylix kq |
| vangs fjeld bortz whump dicky qx | vangs fjeld bortz whump kylix cz |
| vangs fjeld bortz whump picky qx | vangs fjeld bortz whump quick xy |
| vangs fjeld brick whump zloty qx | vangs fjeld brick whump rity qz |
| vangs fjeld brock whump sixty qz | vangs fjeld brock whump xysti qz |
| vangs wecht fjord plumb kylig qz | vangs wecht fjord plumb zinky qx |
| waltz gecks fjord nymph squib vx  | waltz kems bunch fjord vying qx |
| waltz kench bumps fjord vying qx | whack vents fjord plumb zingy qx |
| whang fjeld bortz mucks privy qx | whang fjeld bortz mucks pyxis qv |
| whang fjeld bortz skimp curvy qx | whang kemps blitz fjord curvy qv |
| wrack fjeld thumb zings proxy qv  | dwarf blitz jocks nymph sqeg vq |
| jacks bortz fling whump gyved qx | vangs blitz fjord whump pecky qx |
| wacks blitz fjord nymph sqeg vz  | whack bortz fling jumps gyved qz |
| whang blitz frock jumps gyved qx | whang blitz frump jocks gyved qx |
| whang bortz flick jumps gyved qx | gecks blitz fjord nymph sqaw vx |
| vetch fjord plumb zings gawky qx | vetch fjord plumb zings pawky qx |
| blitz fjord gucks nymph dewax qv  | blitz fjord gucks nymph re wax qv |

### TABLE 4