Speeded Discrimination Training, Fluency, and Generalization in the Laboratory: Training Fluency and Promoting Generalization using Choice Reaction Time (CRT) Tasks

by

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We accept this thesis as conforming
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ABSTRACT

The primary objectives of the present study were to assess the degree to which generalization would occur to novel, untrained stimulus discriminations following fluency training on a variety of choice reaction time (CRT) tasks. A choice reaction time paradigm and a program called "Speeded Discrimination Training" (SDT), which utilized a computer screen and a two-key response box, were used to deliver the probe and training stimuli to the four female participants who were given alternating probe and training sessions in this study. All participants were trained on various decks in tasks comprising homonym phrases, letter pairs, synonym and antonyms pairs, and sentences for which they received per cent correct and rate correct per minute (RCPM) feedback, upon which goals and monetary reinforcement were set and distributed. This study differs from previous work in the author's laboratory as the tasks and exemplars employed in the present study were more difficult, variable and diverse. The tasks were more difficult in that they required the participants to make grammatical discriminations among the stimuli being presented rather than simply discriminating among highly familiar word categories, letters, or numbers as in studies carried out by Kristofferson (1977) and Pashler and Baylis (1991). Evidence for generalization from trained decks to novel, untrained decks within tasks, as well as from trained tasks to untrained tasks, was revealed upon examination of the various figures produced from the participants' probe and training data. Generalization was demonstrated by participants starting at higher levels on successive training decks, for a particular task, than the decks in previous training sessions; participants requiring less time for successive training decks within and across tasks to reach, or exceed, previous RCPM levels; and

participants showing improvement trends across the novel decks in successive probe sessions, as well the tasks that had not yet been trained and only seen in previous probe sessions. Overall, fluency-based training appeared to be successful in promoting generalization within, and in some instances, across speeded discrimination tasks.

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Acknowledgments

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Introduction

The ability to make rapid and accurate discriminative responses to discriminative stimuli (e.g. "4" to the question "what's two times two", "five" to the number "5", or "Same" to the letter pair "A a") is an important skill in many day-to-day activities. For example, being able to recite the multiplication table quickly and without errors might allow one to compute calculations speedily and without hesitation or stumbling that might otherwise lead to confusion and erroneous responding. This phenomenon, which Precision Teachers and others refer to as "fluency", has produced growing interest, and has recently been the object of publications in behavior analytic journals (e.g. Binder, 1993/1996).

Response Speed as an Operant Response

According to the *micromolar approach*, when participants train on a task they learn not only the topography of the task itself but also the speed at which to perform the task (Logan, 1956). What this means is that the speed at which a participant practices a task, as well as, presumably, the length of time the task is practiced at that speed will determine overall performance speed. Therefore, if speed is a desirable result, participants should be instructed to respond as quickly as possible on training tasks (Logan, 1956). To the extent that speed is required in performing tasks that are encountered in day-to-day activities, such as in the classroom or on the job, early training of speeded responses may greatly benefit all individuals in these types of settings.

Precision Teaching and the benefits of Fluency-based Instruction

Precision teaching involves students practicing fluency on classroom material and continually self-monitoring their performance by recording their speed and accuracy on assigned tasks. Charting their performance allows the students to evaluate their own

progress and permits them and their teachers to make adjustments to their individual learning programs that will lead to improved learning (Lindsley, 1992).

Precision teachers attest to the benefits of implementing fluency-training programs in their classrooms. Some precision teachers have even guaranteed that students will gain two grade levels per year by using fluency-training programs with direct instruction (Johnson & Layng, 1992). Behavioral fluency has been found to promote better retention of knowledge and skills as well as their ready application or transfer to higher-level skills or training (Binder, 1993; Binder, 1996).

Teaching in the classroom, as well as learning in other settings, may benefit from research on fluency and the generalization of its effects. For example, if teachers were to implement the use of flash cards (i.e. a term or concept written on one side of a piece of paper, such as a recipe card, and the corresponding definition or explanation written on the opposite side) as a way to increase their students' fluency ability in one area of study, such as the rules of grammar, that skill might generalize to, and thus improve, other areas of study, such as composition.

Lindsley (1995) has demonstrated this type of generalization. Focusing on the variable(s) affecting the acquisition and generalization of fluency skills in the laboratory may provide beneficial information for those training fluency in the classroom (Johnson & Layng, 1992), as well as in other applied settings.

Binder (1993) cites such an example of the benefits of fluency--calculus students who achieved a fluency criterion in particular classes retained almost twice as much, compared to students using a conventional accuracy-only criterion, when tested six weeks after course completion. He also states that "true mastery" of a behavior is achieved when

a combination of accuracy, plus speed of performance, leads to a reduction in distractibility and allows for the application and adaptation of skills to new situations. In view of this statement, one could conclude that students who can make speedy and accurate responses on discrimination tasks may not only retain these skills more efficiently over time, but also be able to more readily apply these skills to learning more complex, novel tasks (Binder 1993).

Some researchers have suggested that fluent performance be defined in terms of its behavioural products (e.g. Retention and Application), as found in the acronym REAPS, that tend to be attained as a result of being able to perform at an adequate speed and accuracy on certain skills or at particular tasks. That is, once a person performs a skill or task fluently--according to these criteria--they tend to display certain behaviours that are classified as fluent performance with respect to that skill or task.

In 1981 Eric Haughton defined the above-stated products of fluency with the acronym R/APS. The "R" represents "retention", the "A" represents "application" and the "PS" represents "performance standards". These fluency products, "retention", "application", and "performance standards", were suggested on the basis of Haughton's belief that the retention and application of trained skills in daily situations were the criteria for determining performance standards for those skills. Therefore, when training skills, Haughton "...aimed at frequencies that would guarantee both retention without regular practice and application in the real world (generalization) without specific practice" (Lindsley, 1995, p. 5). Later in 1981 Haughton recognized that the ability to endure at a task despite outside distractions, passing time, or fatigue was an important result of

fluency training. He therefore added an "E" for "endurance" to his acronym and changed his initial acronym, R/APS, to the modified acronym, REAPS.

Ogden Lindsley played an important role in the transition in the meaning of REAPS from what was originally developed by Haughton. The "PS" in Haughton's REAPS stood for performance standards and served as empirical criteria for judging if behaviour was fluent, and as time passed, the "REA" changed from being goals to products. Due to this shift in the basic meaning of REAPS Ogden Lindsley (1995) modified Haughton's acronym and included additional products of fluency he and others observed in their work with fluency; as a result he created the expanded acronym REAPS FUN CG.

In order to try to promote fluent performance, Lindsley required that his students create flashcards based on classroom materials and become fluent in using them. The objective when using the flashcards was to be able to flip through them as quickly as possible (usually over 1 minute intervals) while maintaining accurate responses. Working with these students who used flash cards, Lindsley discovered that fluent responses remained stable under many distracting situations, and thus changed the "S" in REAPS from "standards" to "stability".

The "F" in Lindsley's "FUN" acronym stands for "fun". Based on his observations that participants and students laughed and giggled while carrying out fluency timings in workshops and in the classroom Lindsley stated, "...it became clear that fluent performing was fun..." (Lindsley, 1995, p. 6). He found that implementing fluency timings at the beginning and end of each of his class sessions and workshops helped to "break the ice" and allowed people to feel more comfortable and motivated to learn.

The "U" in the "FUN" acronym represents "understanding", as Lindsley believes that fluent performance naturally generates a need for understanding. Through promoting traditional rote learning of flashcards, Lindsley observed that his students became motivated to gain an understanding of the terms represented on the flashcards. His students did not want to merely memorize the words or symbols on the flashcards they wanted to understand them. He stated, "...once a term or a symbol has been forced into a student's fluent, motor repertoire, automatically, questions are asked about it" (Lindsley, 1995, p. 6).

The "N" in Lindsley's acronym stands for "no cheating", which Lindsley discovered was a natural consequence of fluent performance. The goal of implementing the use of flashcards and giving fluency-based timings, as mentioned above, was for students and participants to consistently make speedier responses while attaining a high accuracy level. Lindsley realized that as the students and participants became more and more fluent they were not given any opportunities to cheat, as any cheating behaviour (e.g. looking at a neighbour's paper) would only slow down their own performance.

Finally, Lindsley identified "confidence" and "generativity" as products of fluency and completed his acronym by placing "CG" at the end of it. Through his own work, as well as work carried out by Binder (1990), Lindsley recognized that promoting fluent performance among children with disabilities helped to boost their confidence. He urged teachers to work these children beyond normal levels of functioning and "...to practice them far above normal frequencies to championship levels..." (Lindsley, 1995). Children, who were given this super fluent practice, thus achieving superfluency, built up a confidence that no other form of praise or approval could generate. Superfluency refers to

levels of fluency that go beyond ordinary mastery of a skill or task. For example the normative oral reading rate for people who are "proficient" or have a "mastery" of English is somewhere between 150 and 250, or even 200 to 250, words per minute with random errors; someone at a superfluency level might be able to read orally at a rate of 400 words per minute. As an additional example, despite participants' coming into the lab with what we would presume to be fluency with respect to discriminating between "correct" and "incorrect" letter pairs, some were able to improve their RCPM levels from 92.3 to 142.4. In addition to Lindsley's findings, Binder called attention to "confidence" as a benefit of fluent performance in an article he wrote in 1990 that described fluency to industrial trainers. These combined factors prompted Lindsley to add confidence to his acronym.

Lindsley's final product of fluency, "generativity" is represented with a "G" in his acronym. Generativity and generalization are very similar conceptually. Essentially, both terms have come to mean the ability to apply trained skills that have been learned in one situation to different, yet related situations. This is supported by Haughton's discovery in 1972 that "...smooth, fluent application occurs when component tool skills (are) truly fluent..." (Lindsley, 1995, p. 7).

The acronyms REAPS and REAPS FUN CG are important tools in fluency training and generalization research. All of the products represented by these acronyms enable researchers to assess whether or not they are promoting fluency in their own training sessions by serving as a type of "fluency check-list". Although all of the products identified by these acronyms are not always applicable to each fluency-based training session or study, they both have served as efficient indicators in various studies of fluent behavior and its generalization.

The Role of Speed and Accuracy in CRT: SETOL

Laboratory studies of the effects of fluency training often implement a choice reaction time (CRT) paradigm. The CRT paradigm is similar to the use of flash cards in that both approaches involve stimuli being presented, individually and randomly, with only one correct response being reinforced. As with the use of flash cards, speedy responding is an important variable to be promoted in CRT tasks. But a problem arises with the fact that speed, or an increase in speed, often results in an increase in erroneous responding. The speed-error trade-off limit, or SETOL, is a specific measure of this relation between speed and accuracy (Rabbitt & Banerji, 1989).

SETOL is the point, or threshold, at which, for a given level of training or proficiency, accuracy is sacrificed for increases in speed. As implied by SETOL, when participants are given instructions to emphasize either speed or accuracy when training on rapid discrimination tasks, the other element usually suffers as a result (Rabbitt & Banerji). In the present study, participants were instructed to respond on rapid discrimination tasks as quickly as possible (a RCPM goal was set for each block of training) while maintaining a high accuracy level (85 percent or above). These criteria were set in order to promote a continual increase in the participants' speed of responding while maintaining a high accuracy level, as required by fluent performance.

Speedy and Accurate Responding and Performance Plateaus

An important question is raised with regard to performance plateaus, that is, whether performance will continue to improve with further practice. Keller (1958, p.1) states, "the progress curve for most skills is negatively accelerated", which is supported by Newell and Rosenbloom (1981, p. 1-55) who assert that performance progress does

continue to take place, although in much more smaller increments and "...it would be foolish indeed to predict that no further improvements would occur". They do add that the rate of improvement later in training will be slower than the rate of improvement initially, which is a common phenomenon seen in previous work carried out in our lab (Peters, 1996), as well as the present study.

Keller (1958) supplied evidence that suggests that such performance plateaus need not be inevitable. He reviewed the performance of telegraphers who learned Morse code and found that progress was most rapid at the beginning of training, followed by a slower, fairly straight-line advance, or slight deceleration up to the end of training and found little evidence that people reach a stage where they cannot improve on a task with additional training (Keller, 1958). This notion is supported by Fitts (1964) who says in his "late phase" of skill learning that "even in quite simple information-processing tasks such as telegraphy and typing...work performance continues to improve over millions of cycles of practice". It stands to reason then that if in the laboratory participants receive adequate and appropriate training, even on well-learned discrimination tasks, it might be found that they would similarly continue to advance on those tasks. As with Keller's telegraphers, participants could likely even show improvement in speed without an increase in errors. Grabavac (1996) employed operant training techniques (immediate reinforcement and shaping) using a CRT paradigm with similar tasks as the ones used in the present study, which produced evidence that also supports these hypotheses.

Practice Effects, Fluent Performance and Generalization

Both the degree of practice with, and generalization from, a given task influence our proficiency in the skills we use in our daily lives. Although most of our actions in life

are not restricted to simple discriminations between stimuli, studies on simple CRT tasks can reveal some of the phenomena that occur when an individual is trained for accuracy and speed on such tasks. Some researchers have sought to determine the mediating factors that promote the acquisition and generalization of fluent performance in order to develop training programs that will yield productive transfer to novel tasks. For example, Pashler & Baylis (1991) state "in applied settings, it would be useful to know how conditions of skill acquisition can be structured so that learning is more efficient and to know when one form of training will produce useful transfer to other, related tasks.

As mentioned above, practice effects may be evident in both speed and accuracy as a result of considerable, as well as small amounts, of practice on rapid discrimination tasks (Grabavac, 1994). Pashler and Baylis (1991, p. 21) note, " Transfer might occur even when stimuli are introduced that are physically different from those used in training".

The Kristofferson Study

Kristofferson (1971) examined practice effects by using an item-recognition task, which required participants to indicate whether or not they recognized a previously presented stimulus by pressing one of two keys. Two sets of target stimuli, A and B, were each made up of two, four, or six letters (for a total of 12 letters per set) and were alternated from session to session; these were referred to as "positive" sets. The target stimuli were randomly selected from the 26 letters of the English alphabet and were represented in orders determined by random selection without replacement. The distractor, or "negative", stimulus sets were selected by drawing 8 letters randomly from the 14 remaining letters (after the positive sets were formed) and these items remained constant throughout the trials (i.e. the same distractor stimuli were used for all participants

across the three different groups). In each trial the participants were visually presented with a single stimulus, which was either a target or a distractor, and were instructed to press the "Yes" key to indicate that they recognized the stimulus they saw (i.e. a target stimulus), or the "No" key to indicate that they did not recognize the stimulus (i.e. a distractor stimulus). They were instructed to respond as quickly and accurately as possible and were given auditory feedback on their performance for each trial.

During the testing phase, participants were randomly assigned to one of three groups: old, old-mixed, or old-new mixed. Participants in the old group were tested under conditions similar to the training conditions (i.e. they were presented with old, previously seen stimuli that belonged to either the A or B target set). The old-mixed group received stimuli that were novel combinations of previously seen stimuli from the old target sets of stimuli (i.e. they were presented with the same target and distractor letters as seen in training, except that they were now a new combination of the original two sets). In the old-new mixed group the participants were given target sets of stimuli that included a mix of old target set stimuli as well as novel, previously unseen stimuli (i.e. they were presented with a combination of previously seen, as well as novel, target and distractor letters).

Kristofferson hypothesized that if participants' responding was under the control of the individual target stimuli, than the reaction times (RTs) for the old and old-mixed group would be comparable and both groups would have faster RTs than the old-new mixed group. This would occur because participants in the old and old-mixed groups would be presented with more familiar stimuli than the participants in the old-new mixed group. However, if instead responding was under the control of connections made between the

stimuli in each target set developed during training, RTs for the old group would be faster than both the old-mixed and old-new mixed groups. The reasoning behind this was that the participants in the old group were presented with the same stimulus-set relations in testing and training and therefore would have likely retained the stimulus relations they were exposed to in their training sessions. As well, the old-mixed group performance would be better than the old-new mixed group performance because some of the stimulus relations presented in testing to the old-mixed group would be similar to those they had seen in training.

Kristofferson found that there were no significant differences in the RTs across all three groups in testing, which indicated that complete transfer had occurred from the training conditions to the testing conditions. These data suggest that generalization may occur in relatively simple CRT tasks even though specific programming for generalization has not taken place (Kristofferson, 1971). Kristofferson (1971, p. 185) concluded that "...whatever is learned in the practice stage and is reflected in the changes in the set-size effect over the course of practice is transferred very well indeed to new items..." and "...practice effects on the set-size effect transfer exceedingly well to unpracticed items". However, this improvement and transfer might also have been a result of more general factors such as learning to focus on appropriate cues within the stimuli presented or learning not to engage in potentially distracting covert behaviour. Further, as with the Pashler and Baylis study described below, Kristofferson used fairly simple stimulus-response relations in this study and the question remains: Can fluency be trained, and generalization promoted, across tasks involving more difficult stimulus discriminations?

Additional research in fluency training and generalization, involving a more diverse range of CRT tasks, is needed to answer these questions.

The Pashler and Baylis Study

Pashler and Baylis carried out CRT studies that required category discriminations among numbers, letters, and symbols and assessed whether generalization would occur to novel stimuli in these same categories. Their participant's performance followed a negatively accelerated pattern, their RT's declined significantly over the first 6 blocks of training and then remained fairly constant through to the 15th block, at which time the transfer stimuli were introduced and an increase in RT's was produced.

Overall, they found that considerable generalization did occur to novel stimuli in their tasks and stated that "the latency results show a high degree of transfer to new items in old categories" and that "new items in the trained categories enjoyed virtually the entire benefit obtained by the old (previously trained) items in these categories..." (Pashler & Baylis, 1991, p. 25). They considered a number of hypothetical constructs to explain their results, two of these were 1) the highest link or inclusive links hypothesis, and 2) the response execution speedup hypothesis. The highest link hypothesis states, "the effect of practice is to strengthen the link between the highest level node that is consistently mapped onto a particular response and the corresponding response node (i.e. the link between the letter category and the response category)...and would predict transfer to new exemplars of a category, so long as the mapping of categories to responses remained the same". For the different letters in the letter task ("G", "L", "R") the highest-level node would be the property "LETTER" (the categorical stimulus) which all letters share in common and consequently would mediate, thus share, the same response on the response box. So, for

example, when examining the connection between the presentation of the letter "G" and a response of pressing the "letters" key on the response box, the "links" or relationships required would be as follows. The letter "G" would have to evoke the covert response "letter", and then that stimulus, "letter", would have to evoke the overt button press response on the "letters" key. The inclusive links hypothesis states, "practice builds links to a response from all of the nodes that are consistently associated with it" (Pashler & Baylis, 1991). For example, responding is not only facilitated by the "LETTER" property, but by the individual properties of each letter (i.e. the "G-ness" of "G" or the "L-ness" of "L"); again, these would require the same responses on the response box. The execution speedup hypothesis states that practice facilitates the execution of motor responses and therefore any time a new stimulus requires the same motor response as a trained one, transfer will be expected to occur (Pashler & Baylis, 1991). The execution speedup hypothesis received little support, insofar as Pashler and Baylis found complete transfer to the hand opposite to that used in training.

Despite the importance of their favorable results (i.e. considerable generalization from trained to novel items within their category tasks) one cannot overlook the fact that the tasks used by Pashler and Baylis involved very simple stimulus-response relations and may not be widely applicable to every day, "real-world" skills and tasks. For example, the number task they used involved simply being able to respond correctly to the test numbers "4" and "9" after having been trained to respond quickly on the "NUMBER" key to the numbers "2" and "7", or vice versa. Numbers are something that people have generally had a lot of practice on all their lives and, as well, there are limited responses that one could emit upon seeing a particular number. For most people the ability to manipulate

simple, single-digit numbers is generally a highly over-learned skill, and as well, Pashler and Baylis only looked at whether generalization would occur to stimuli within the same category as those trained, and not at whether generalization would occur across different categories. Their results do not allow one to speculate as to whether or not generalization might occur in situations of diverse stimulus discriminations or across different stimulus categories.

Generalization Mechanisms: Stimulus Classes

The type of generalization demonstrated by Kristofferson and by Pashler & Baylis does not seem to be accountable in terms of common stimulus properties (i.e. when a single stimulus guides one response in one training context and another response in a different test context, mediated by common physical stimuli). The classical model for generalization is one in which the same response generalizes across stimuli on the basis of common physical stimulus elements -- e.g., from one red stimulus to another different, but still red, stimulus. In the present study, (and in some of the CRT literature reviewed here), the stimuli do NOT share common PHYSICAL elements (e.g. Pashler and Baylis' letters). In this respect, the classical model differs from the previously discussed hypothetical constructs of Pashler and Baylis, the central difference being that Pashler and Baylis' "link" analysis is couched in more hypothetical, more mentalistic brain models than is the classic generalization model. Therefore, to account for the generalization seen in these types of studies, some different or additional mechanisms must be invoked. One possibility is functional stimulus classes in which physically different stimuli share a history of controlling the same responses.

Functional Equivalence

How else might this generalization occur? Let us assume that in the Pashler and Baylis study when participants were shown the stimulus "2" there were two covert responses they could emit; the participant could respond to the stimulus as either "two" or "number". On the basis of prior learning, the participants were able to label the stimuli in these two ways, by the numeral represented and by its category name which allowed them to make very quick overt responses on the response box. Therefore, when given a "novel" number such as "9", participants were able to respond quickly due to the fact that "9" requires the same covert response of "number" and the same button press response on the response box; this would seem to be the case for any "novel" number presented to a participant. This type of mechanism is what defines "functional equivalence"; stimuli that are functionally equivalent are said to belong to functional stimulus classes. Donahoe and Palmer's (1994, p. 357) textbook definition of a functional class is "a range of stimuli that may differ physically but have similar uses and control common responses". They go on to say that "stimulus classes form not only when stimuli within the class are physically similar-as in discriminative stimulus classes-but also when stimuli within the class guide similar responses due to common consequences" (Donahoe & Palmer, 1994). For example A and B, which are both physically quite different, are discriminative stimuli (SDs) for the response "letter".

In the present study the participants were required to respond "correct" or "incorrect" to the stimuli presented based on particular instructions. The stimuli that comprised each task could be considered functionally equivalent in that the exemplars in each deck, of each specific task, were physically dissimilar and came to guide either one of

two button presses responses on the response box ("correct" or "incorrect") and, particularly important, have a history of doing so with respect to responses other than those employed in the lab (e.g. in grammatical lessons learned in English class).

With this in mind, it can be assumed that any exemplar that would become a part of each task's functional class, with respect to the responses and response properties required (i.e. speed), would come to control either the "correct" or "incorrect" response. If the exemplars are becoming part of each task's functional class, this might be a major factor contributing to the mediation of generalization from trained to novel, untrained sets of stimuli within each task.

Two other factors that might mediate the type of generalization described above, and seen in the author's work, could be a "learning to learn" phenomenon (i.e. prior training allows participants to learn and make subsequent discriminations more quickly), (Postman, 1972) and/or the formation of activation networks (ie. within neuronal models, and may in fact implicitly refer to the same kind of mechanism as functional class-based transfer, but just in different terms). These concepts are further discussed in the conclusions section.

In the present study the types of transfer being examined -- across different items within the same task and across different tasks -- are of interest, in part, as an objective way of determining to what extent transfer will be mediated based on the kinds of more complex, and not always clear, mechanisms described above.

Maximizing Generalization Through Variety

Duncan (as cited in Kling and Riggs, 1971) found that training a greater variety of tasks produced greater transfer effects than training fewer tasks when the amount of

practice was held constant. Duncan used non-verbal paired-associate tasks in which participants made responses on a lever to visual forms used as stimuli. The participants were trained on 1, 2, 5, or 10 different tasks and received varied amounts of practice (either 2, 5, or 10 days of practice, 20 trials per day); all groups trained on two common final tasks. Duncan found that improvement in performance on untrained tasks was "found to be a direct function of both the total amount of practice and the degree of variation in training" and that when the degree of variation was held constant transfer increased with the amount of practice. Duncan (1958) suggested "...that experience with a variety of tasks renders the subject increasingly sensitive to the relevant dimensions of the stimulus terms" and that "it is of value to look carefully at each stimulus presented, not only to its obvious characteristics, but also to any minor details".

Stokes and Baer (1977) support Duncan's idea by stating that the apparent path to generalization is to train on a variety of tasks, as training on only one task results in the mastery of that particular task without producing any transfer beyond that specific task.

Evidence for the effects of varied training in the context of laboratory CRT tasks is provided by Schneider and Fisk (1984), who found that individuals who learn to discriminate between various categories show increased generalization to novel stimuli within those categories when they are trained on a variety of exemplars. Schneider & Fisk (1984) studied consistently mapped semantic search tasks (e.g. RT for identifying the location of single target words from a given category in a 3-word column; i.e. "rifle" for category "weapon") and found considerable positive transfer from trained to untrained exemplars in the same trained category. They also found that having more exemplars in the training set produced superior transfer; 60% transfer with 4 exemplars vs. 92% transfer

with 8 exemplars, which is consistent with the assumption that one must train using a variety of stimuli and conditions to promote greater generalization.

The idea put forth by the above researchers, that training on a variety of tasks promotes greater transfer, bears on findings from studies that have focused on elite performers. Ericsson and Charness (1994) found that contrary to conventional wisdom, the achievements of expert or elite performers results primarily from sustained periods of deliberate practice rather than innate talent. The superior skills acquired due to this deliberate practice are highly specific to the expert's domain and the expertise of elite performers does not tend to generalize to skills outside of the domain in which they have practiced (Ericsson & Charness, 1994). The implication, therefore, is that training across a wider domain of tasks might promote more generalization of skills.

Past Research in Our Laboratory

In previous work carried out in our laboratory (Peters, 1996), the author employed a similar CRT paradigm, apparatus, and design as in the present study, but the tasks and procedure used differed in significant ways from the one employed presently.

Participants trained on a series of simple categorical, letter-pairs and numbers tasks and were required to respond on a three-button response box, as opposed to the two-button response box used in the present study. Each category task comprised three categories and each category was mapped onto one of the keys on the response box [e.g. color (blue)-left key, profession (doctor)-middle key, instrument (guitar)-right key]. Each individual category had only five exemplars representing it. For example, the color category would have only contained the colors blue, red, green, yellow, white, which allowed for a great deal of repeated exposure to each set of the exemplars during training in each task. The

letters/numbers tasks were made up of three types of letter/numbers pairs, with each letter/number-pair type being mapped onto one of the three buttons on the response box. For the letters task the letter-pair types were "identical" (same letter, same case-left key), "same" (same letter, different case-middle key), or "different" (different letter, same or different case-left key) and for the number task the number-pair types were "greater than" (the first number in the pair was greater than the second number-left key), "less than" (the first number in the pair was less than the second number-middle key), "equal to" (both numbers were the same-right key).

All four participants trained under the same conditions (i.e. they trained on a given task for a set number of days before moving onto a different task); but, as in the present study, they received randomized training schedules (i.e. participants were not training on the same decks at the same time) in order to try to minimize deck effects as the cause of apparent generalization effects. In contrast to the present study, previous probe sessions were administered over a two or three day period. This was initially done in order to get a more stable reading of the probe data, but was modified in the present study for the reasons listed below.

How the Present Study is Different

Following the re-evaluation of past paradigms and designs employed by the author in previous studies, and conferring with investigators experienced with speeded response training (personal communications, Bram Goldwater and Joe Parsons, February, 1999), the author modified the design and methodology from our previous work in order to address the objectives as laid out in the method section.

First, the tasks and exemplars employed in the present study were more difficult, variable and diverse than ones used in our previous studies. The tasks were more difficult in that they required the participants to make grammatical discriminations among the stimuli being presented rather than simply discriminating among highly familiar word categories, letters, or numbers. In addition, the tasks that were chosen involved more complex stimulus-response relations than those seen in our previous work, as well as the work of Pashler and Baylis and Kristofferson.

As recommended by Duncan (1971), Schneider and Fisk (1984), and Stokes and Baer (1977) the author chose to use a wide assortment of stimulus decks and tasks. By using a variety of diverse decks the author attempted to promote, as implied by many of the researchers cited above, greater variability during training and, as a result, encourage greater generalization across verbal tasks of diverse stimulus-response relations. Second, a "same-deck" and "variable-deck" condition (which will be described more thoroughly in the methods section) were implemented to better evaluate the degree to which continually training on the same deck differs from training on a variety of decks in the promotion of transfer from trained to untrained tasks.

Third, there were many more stimulus decks available for the training sessions in the present study compared to our previous work. Having more training decks limited the exposure to, and thus learning time on, each specific deck and the exemplars in that deck. This provided a clearer measure of actual generalization effects as opposed to practice effects due to familiarity of the decks/exemplars because of continual exposure to them.

Fourth, the three-button response box was changed to a two-button response box (by taping over the third key) and the mapping of the buttons was kept constant for each

task presented (i.e. the left button always denoted "correct" and the right button always denoted "incorrect"). This was done in order to put less emphasis on selecting the appropriate button to press and more emphasis on correctly categorizing the exemplars seen, and thus, hopefully, reducing the variance attributable to these button-selection types of errors.

Finally, probe session testing on untrained, novel tasks was limited to a one-day session, as opposed to the two or three day sessions of our previous work. This modification was made in order to better evaluate whether transfer of improved discrimination speed to untrained, novel tasks was indeed occurring or not without being able to attribute the findings solely to being a result of substantial practice effects within the probe sessions themselves.

Method

The Objectives

The objectives of this study were threefold. 1) The first objective was to determine whether improvements in discrimination speed, attained on a variety of decks from specific tasks, would transfer to untrained, novel exemplars within those tasks. In contrast to previous work in our laboratory, exposure to these decks involved relatively limited repetition of the given exemplars, thus requiring continual transfer across the exemplars in the given decks. 2) The second objective was to evaluate whether the improvements in discrimination speed attained on a variety of decks (i.e. sets of stimulus items), from specific tasks, would transfer across the different rapid discrimination tasks in the study. 3) The third objective was to try to determine whether daily training with varying stimuli promoted greater generalization than training on the same stimuli every day.

Participants

Four female undergraduate psychology students from the University of Victoria were recruited from an upper level behavioral psychology course to participate in this study. All four participants took part in this study as a partial fulfillment of the course requirements of an independent study course.

Materials

The training and testing materials used in this study were CRT tasks consisting of simple and over-learned stimulus discriminations and, therefore, the level of speeded discrimination observed, as a result of training, went beyond what is generally dealt with in the Precision Teaching/Fluency literature, a phenomenon that has been called "superfluency", which was discussed above.

The discrimination to be made by the participants was whether a stimulus was either "correct" or "incorrect" in the context of four different tasks: homonyms, synonyms vs. antonyms, letters, and sentences. The homonyms task was made up of decks of 3-5 common word phrases, each with a correct or incorrect use of a homonym taken from a number of homonym pairs and/or triads. These decks were developed by the author and were used in the initial phase of the present study. The "original" homonyms decks were made up of phrases made from a selection of homonym pairs, whereas the "familiar" homonyms decks were made up of different phrases containing the previously used, therefore familiar, homonym pairs. That is, the homonyms used in the familiar decks were the same as the ones seen in the original decks, but combined into novel phrases.

Each of the homonyms decks were composed of 20 phrases, with 10 of the phrases being correct and 10 the phrases being incorrect. When doing pilot work with the

homonyms phrases it was found that in a 20-second trial the author, who had had much prior practice on similar CRT tasks, was only able to respond to 12 or 14 homonym phrases. Therefore, to be on the conservative side, the author chose to use 20 homonym phrases per deck to ensure that participants would not be exposed to repeated stimuli on a given trial. Each homonym phrase in a pair was chosen to be correct or incorrect by flipping a coin, and then it was assigned randomly to a deck, with the sole restriction being that the two homonyms in each pair (e.g. board/bored) were never assigned to the same deck. So, in a given deck, the meaning of each homonym was held constant. Participants were required to decide whether the homonym in each phrase was used correctly or incorrectly based on the context (i.e., the particular phrase in which it was embedded, such as bored silly=correct, black bored=incorrect).

The discriminations required in the other tasks which were included in this study comprised synonyms vs. antonyms word pairs ("correct" if the pair of words were synonymous, "incorrect" if they were antonymous); same vs. different letter pairs ("correct" if the two letters were labeled the same way, regardless of upper or lower case, "incorrect" if they were different); and, grammatically correct vs. incorrect sentences ("correct" if the sentence was grammatically correct, "incorrect" if it was not). See Appendix A for a more detailed sample of correct and incorrect exemplars for these tasks.

Apparatus

In our laboratory, a choice reaction time (CRT) paradigm has been used previously, and was used presently, to promote fluent responding on a variety of discrimination tasks. Research in the author's lab using a CRT paradigm to train speeded discrimination has demonstrated that improved speed of discrimination on simple category

tasks (e.g. responding "fruit" to "apple" on a response box) will generalize to novel, untrained category tasks (e.g. responding "instrument" to "trumpet" on the same response box).

Our use of the CRT paradigm was by means of the "Speeded Discrimination Training" (SDT) computer program, designed by Bram Goldwater and Diana Grabavac, and programmed by Tom Allen. The SDT program presents, in a random order on a computer screen, of a series of stimuli, records the participant's responses and response latencies, and provides feedback based on the participant's performance. Each stimulus was discriminative for one correct, "reinforced" response on a response box, and the rate correct per minute (RCPM) level, which improved or declined based on speed and accuracy of a given trial, was displayed on the screen at the end of each trial. RCPM will be further discussed below. The three-key response box was modified so that only two buttons were available; the responses "correct" and "incorrect" were mapped onto these two buttons for the different tasks. We taped over the button furthest to the right on the response box in order to prevent participants pressing it accidentally; none of the participants reported pressing this third button at any time during this study.

Design

A single-subject design with four participants was used in this study. Each participant's data were individually reported, examined and interpreted by daily graphing the results of each training session. Specifically, a multiple-baseline-with-probes research design was employed, in which the duration of "baseline training" with the same homonym phrases varied across participants, and performance on both trained and

untrained tasks was repeatedly assessed (probed) before, at regular intervals during, and at the end of training (Kazdin, 1982).

Procedure

As mentioned above, a series of tasks employing original homonym phrases, familiar homonym phrases, letters, synonyms vs. antonyms and sentences was used in this study. Each task employed anywhere from 5 decks (as with the letters decks) to 30 decks (as with the homonyms decks) which were used in probe and training sessions.

Probe Sessions

Probe sessions were placed strategically at the beginning, during, and at the end of the study; these sessions were used to enable repeated comparison of discrimination speed with pre-training performance. In each probe session, and for each task, there was 1) one "constant deck", which appeared in every probe session but was not trained, 2) one "novel deck" specific to each probe session that had neither been trained nor presented, and 3) one or more "to-be-trained decks" (not yet trained, but to be trained in a subsequent training sessions) or "trained decks" (already trained in a previous training session), depending on the deck and the probe session number. Participants received five 20-second trials per deck in the baseline and probe sessions.

Each probe session was followed by 3 to 8 days of training on a series of decks from the subsequent training task. Each participant was randomly assigned to begin under one or the other of two training conditions, with two participants being in each condition. In the "same-deck" condition, participants trained daily with the same homonym deck for five days before switching to the "variable-deck" condition. In the "variable-deck" condition, the participants trained on varying homonym decks that changed across blocks

within each daily training session, as well as across day-to-day training sessions. Participants who began in the variable-deck condition remained in that condition throughout the study and for all tasks trained. The two participants who began in the same-deck condition switched to the variable-deck condition after the first week of training, as mentioned above, and then remained in the variable-deck condition for the remainder of the study and for the rest of the tasks trained. Comparisons of performance on the probe session, which immediately followed the same and variable conditions, allowed for the evaluation of whether repeated training on the same homonym deck differs from training on varying homonym decks in improving performance and its generalization.

In probe sessions 4 and 5 the participants ran through the same set of decks first with their right hand (probe session 4) and then, for the very first time, their left hand (probe session 5). This was done in order to compare right-handed performance with left-handed performance and to determine whether or not motor skills alone were accounting for generalization. This is further discussed in the "Results and Discussion" section.

Training Sessions

Each training session comprised 3 blocks of 15 20-second trials for a total of 45 trials per session on a single deck for the participants who started in same-deck condition. In the case of those participants who started in the variable-deck condition, they received a total of 45 trials divided into 3 15-trials blocks, each block with a different deck. Each trial consisted of the random presentation of correct and incorrect exemplars from the task being trained with a response-stimulus interval (i.e. the time between the participants' response and the presentation of the next stimulus) of 300 milliseconds.

To promote improved performance on the training tasks, participants were given protracted training across these tasks. This training included shaping and monetary reinforcement, as well as specific training contingencies. That is, in order to be monetarily reinforced, each participant was required to achieve 85 percent accuracy as well as to meet or beat a pre-set RCPM goal for each 15-trial block of training. Participants' performance was shaped by continually adjusting the RCPM goal, as described below, and by maintaining the accuracy requirement.

The participants were instructed to respond as quickly and as accurately as possible, as required by the set RCPM and accuracy criteria. On each trial a "beep" was heard when a participant responded correctly, and silence followed incorrect responses. After each 20-second trial, the participants received feedback on their performance in the form of the average percent correct and the RCPM for that trial. RCPM was computed as the total number of correct responses divided by the sum, in minutes, of all the latencies for correct and incorrect responses. Percent correct is a measurement of accuracy only, whereas RCPM is a measurement of speed and accuracy and provides a single estimate of the participant's overall performance.

As well as trial-by-trial feedback, the participants were also given feedback of their average percent correct and RCPM for each block (15 trials) of training. After each block of training, the participants were required to plot their average RCPM on a graph, for a total of three plots per training session. All of the participants' graphs were displayed together which allowed the participants to monitor their daily progress, to see the degree of improvement that was required to meet the next day's RCPM goal, and to see how they were performing compared to the other participants.

Goals and Reinforcement

Monetary reinforcement was awarded contingent on the participant's performance. Daily goals were set for each participant, and they had to meet or beat these goals in order to receive this monetary reinforcement. These goals included a RCPM goal (which was set independently for each block of training), as well as a percent correct goal (set as a constant at 85 percent) for each block in a training session. The participants' opinions were essential to the goal setting process, and they were encouraged to indicate whether they felt a particular goal would be too difficult or too easy to achieve based on their previous performance. The goals were always set so that they were challenging, yet said to be attainable by the participant. The participants were given $2.50 for every block in a training session on which they achieved 85 percent correct or above, and met or beat their RCPM goal. If they met those criteria on all three blocks in a training session, they received a flat sum of $10.00 for that session. Participants were not given monetary reinforcement during the probe sessions because probe sessions were seen as tests of generalization effects and non-reinforcement would hopefully have minimized training effects on the trials received in the probe sessions. However, as in the training sessions, participants were equally encouraged to make speedy and accurate responses during the probe sessions and were given performance feedback in these sessions.

On the first day of training, the participants and the author looked at the RCPM achieved in the initial probe session on the homonym deck or decks that were "to-be-trained" in order to set the goal for the first homonym training session. For the following training days, the participants and the author looked to the previous day's RCPM values and set the first block's RCPM goal according to those numbers, and then set subsequent

block's RCPM goals based on what the participants achieved in each block of training thereafter. This method was used for all of the tasks trained and for each of the training conditions. For example, if in the initial probe session a participant achieved an average RCPM of 70.0 on the homonym deck "to-be-trained", their RCPM goal might have been set at 75.0 for the first training deck for that task. Then, if on the first homonym deck trained the participant achieved 80.0 as their best average RCPM, the next training deck's goal might have been set at 85.0, and so forth. However, if the participant achieved a rate lower than the goal set (e.g. 72.0) on the deck being trained, the next training deck's goal might have either stayed at 75.0, or lowered by one or two increments to ensure that it was still challenging to, yet achievable by, the participant. That is, each block's goal in a training session was set according to the average RCPM achieved on the 15 trials of the previous training block.

In the present study, the goal adjustments generally followed a 5-point increase when the previously set goal was met or beat. However, as mentioned above, depending on the specific performance on each block of trials being trained and the participant's reaction to the block, these increments might have only increased by 2 or 3 points, the goal may have remained the same as the previous block, or the goal may have been lowered by 2 or 3 points.

Deck Effects

In order to try to minimize deck effects having an influence on the generalization data each of the participants was assigned to different training schedules. That is, the order in which each participant received their training on specific decks differed from the other participants (see Appendix B for each participant's training schedule). This was

done so that when examining the data at a later time performance at a particular stage of training could not be solely accounted for on the basis of the ease or difficulty of the discriminations within the particular deck involved at that training stage. These steps were taken in an attempt to decrease the possibility that any training or generalization trends seen in the participants' data were due simply to them receiving harder decks (represented by lower scores) early in training and/or easier decks (represented by higher scores) later in training.

Evidence of Generalization

Evidence of generalization within and/or across tasks might consist of any or all of the following findings: 1) successive training decks, for a particular task, start at higher RCPM levels than the decks in previous training sessions; 2) it requires less time for successive training decks within and across tasks to reach, or exceed, previous RCPM levels; and, 3) participants show improvement trends across the novel decks in successive probe sessions, as well as on the tasks that had not yet been trained and only seen in previous probe sessions.

Results and Discussion

Did Training Improve CRT Performance on the Trained Tasks?

The data collected in this study are presented in graphic form. Please refer to Appendix C for a list of these figures and their titles.

Figures 1 and 4 present data that reveal the effects of direct training on the original homonyms decks. Each plotted point represents the block-by-block data shown as an average of the 15 trials within each of the three blocks on the same deck, which made up one of the three training blocks for each training day. Figures 21 and 24 present the

average RCPM level for each three-block training day in order to gain a clear picture of the training trends for each task; each task is separated by a space and labeled accordingly.

For Participants 1 and 4, who started out the study in the same-deck condition, the first five days were comprised of a single deck of homonyms (i.e. H07 for both participants) that was repeated over the three blocks of each training day (figures 1 and 4). Upon analysis of figures 1 and 4, as well as the "original homonyms" data in figures 21 and 24, it becomes clear that Participants 1 and 4 show a negatively accelerated pattern of improvement (Newell & Rosenbloom, 1981). That is, performance levels started out low, showed dramatic increases early in training, and then tended to level off as training progressed.

Over the 15 blocks of training on the original homonyms deck, Participant 1 (figures 1 and 21) continued to show steady, gradual improvement right until the fifth day of training, whereas Participant 4 (figures 4 and 24) reached a plateau in improvement around the eighth block of training, with only slight improvements thereafter.

Did Training Effects Transfer within Tasks?

Patterns of Improvement Across Training Decks-Original Homonyms

As expected, when switched from the same-deck condition to the variable-deck condition, while still training on the original homonyms task, Participants 1 and 4 showed a decrease in their performance rates. This is likely due to the fact that they were now receiving three different decks each training day as opposed to the receiving the same deck repeatedly each day prior to the condition switch. This decrease in performance levels could also be attributed, in part, to the fact that the switch in conditions followed the second probe session as well as the university's reading break period which translated into

a long break between training days (7 days); this is in contrast to the one-day breaks in training during the regular training week, or the two-day break due to the weekends. Although Participant 1 started at a lower level on the first block of training after the condition switch (compared to the first block received on the first training day) and therefore had more room for improvement, one cannot dismiss the importance of the fact that Participant 1 was now receiving a different deck for each block of training in the variable-deck condition and still showed improvement.

When switched from the same-deck condition to the variable-deck condition Participant 4 (figure 4) actually started at a higher level in the variable-deck condition and showed a substantial increase from the first block of training to the second block of training. Moreover, on each of the three days of training after the switch to the variable-deck condition, Participant 4 started at a slightly lower level for each subsequent day of training, but showed a large increase between blocks 1 and 2, and only showed slight decreases from block 2 to 3 on two of the three days. However, not only does Participant 4 begin at a lower level each day on block 1, blocks 2 and 3 never get back to as high a level as on the first day of variable training. Overall Participant 4 (figure 24) showed a slight decrease in performance when switched into this new condition, but at no time fell below the initial level of training achieved on the first day in the same-deck condition. This pattern of improvement from block 1 to block 2, on each day, with no carry over to the first block of each subsequent day of training, might be interpretable as reflecting some general type of influence such as "getting familiarized" with the task again after a 24-hour break. For example, this may represent a kind of rapid return of stimulus control by pertinent, as opposed to extraneous, cues.

In contrast to Participant's 1 and 4 same-deck training condition for the first 5 days of training on the original homonyms, Participant 2 and 3 were in the variable-deck condition and received continually varied decks across daily blocks of training (i.e. they never received the same original homonym deck twice throughout training on this task). Figures 2 and 3 present Participant 2 and 3's block-by-block data on the original homonym decks and figures 22 and 23 present their average daily performance across all tasks. In these figures, Participants 2 and 3 show a generally positive trend across blocks and sessions with occasional plateaus and/or reversals (i.e. a drop in performance levels that are similar to prior training levels). The improvements that were made by these participants cannot be accounted for simply in terms of the gradual strengthening of the same stimulus-response relations as Participants 2 and 3 were presented with many different stimuli, with limited, if any, repetition of these stimuli within in each training trial. Further evidence of generalization is demonstrated in that Participants 2 and 3, who also experienced the long break between training days at the time of the reading break which coincided with the switch from the same deck to variable deck condition for Participants 1 and 4, showed little, or any, decrease in performance levels following the break. In fact, Participant 3 (figure 23) started at exactly the same level after the 7-day break as before the break and showed continual improvement each day thereafter. Participant 2 (figure 22) started at a slightly lower level after the break, but also showed continual improvement thereafter, exceeding any performance seen before the break. While this might be suggestive of participants having better retention of whatever it is that is being generalized (e.g. a learned skill or strategy), this might also indicate a transfer effect.

As mentioned above, figures 21 through 24 show the average RCPM level across the three blocks for each daily training session for each successively trained task. All four participants showed at least some evidence for improvement across decks, consistent with transfer within at least one of the four tasks. As well, all tasks were associated with evidence for generalization across decks; both Participants 3 and 4 showed at least some suggestive evidence for generalization within each one of the four tasks. That is, the findings follow the previously mentioned factors that might be considered evidence of generalization, such as successive training decks for a particular task starting at higher RCPM levels than the decks in previous training sessions and/or it requires less time for participants reach, or exceed, previously achieved RCPM levels. Further, with the exception of training days 1-5 for Participants 1 and 4 (while they were still in the "same-deck" condition) and the few decks that had been previously probed, each day of training involved entirely new decks. This continual improvement across decks suggests that effects of training generalized to never-seen-before exemplars within each task.

Patterns of Improvement Across Training Decks-Familiar Homonyms

Figures 5 through 8 present data that reveal the effects of direct training on the familiar homonyms decks. Each plotted point represents the block-by-block data shown as an average of the 15 trials within the same deck, which made up one of the three training blocks for each training day; each block of training consisted of a different familiar homonyms deck for each of the 8 days of training on this task. Day-by-day average RCPM data for this task is also plotted in figures 21 through 24.

Participants 1, 2 and 3 show a similar trend as they all display a fairly consistent and steady horizontal pattern on the familiar homonyms task. All three participants begin

the task at approximately the same level as where they ended with the original homonyms task and end the familiar homonyms task at a similar level as where they started it, with a few variations occurring in Participants 2 and 3's data. For example, Participant 2 starts this task at a slightly higher level than where she left off with the original homonym task, and Participant 3 shows a slight increase in days 6 and 7 and then a drop in progress on day 8. However, overall none of these three participants show the large variations in their RCPM levels as seen in Participant 4's data. Participant 4 starts at a level slightly higher than where she left off with the original homonym task and shows a lot of variability throughout her training on this task. Overall, she ends at a much higher RCPM level than previously achieved in training on the original or familiar homonyms tasks in the variable-deck condition.

Patterns of Improvement Across Training Decks-Letters

Figures 9 through 12 present data that reveal the effects of direct training on the letters decks. Each plotted point represents the block-by-block data shown as an average of the 15 trials within the same deck, which made up one of the three training blocks for each training day. Each block of training consisted of a different letter deck and these three blocks were repeated for each of the 3 days of training on this task. That is, each participant saw the same three letter decks in different training orders (as dictated by their individual training schedules) for each of the three days of training on this task. This was necessary due to the limit of 26 letters in the alphabet and the resulting limited amount of decks that could be created for this task. Day-by-day average RCPM data for this task is also plotted in figures 21 through 24.

All four participants showed the same trend of progress on the letters task. Not only did the letters task have the highest RCPM scores among all tasks in the very first probe session, but all four participants started and ended at a considerably higher RCPM levels than where they started or ended at in any other sessions preceding or succeeding the letters task; they also showed continual improvement over the three days of training on the letters task. Participants 1 and 4 started the letters task, with a deck they had never seen before, at approximately the same level as where they ended after 5 days of training on the same original homonyms task. One must keep in mind that the letters task was inherently an easier task for all four participants, as it consisted of over-learned stimulus-response relations, however, these trends might also be an indication of some sort of transfer of speed or skills acquired from prior training on the homonyms task.

One way to determine if this improvement on the letters task was due to it simply being an easier task or because the training on the letters was influenced by prior training on the homonyms task would be to conduct another study in which one group of participants trains on the homonyms task first and another group of participants begins training on the letters task first; thus allowing one to make comparisons between two groups of participants that would have no prior training on any other tasks from which to have generalization effects. Therefore, any differences in initial performance, final performance, and/or in the rate or degree of improvement, would have to reflect the nature of the task and not outside, confounding variables (i.e. other tasks). Although, one could always argue that a participant in the group who trained on the letters task first, or conversely on the homonyms task first, was a "better learner" and would have done equally well on either task no matter when it was trained, the researcher would have to

ensure that all participants involved in the study were randomly assigned to each training condition to account for individual variability and hopefully minimize this possible confounding variable.

At any rate, this study did not include the type of design discussed above in its methodology (i.e. training groups of participants on different tasks in different orders), and, therefore, did not produce data with which to compare the different performance rates that might have been revealed if one task was trained first with one group of participants and another task was trained first with another group of participants.

Patterns of Improvement Across Training Decks-Synonyms

Figures 13 through 16 present data that reveal the effects of direct training on the synonyms decks. Each plotted point represents the average of the 15 trials within the same deck, which made up one of the three training blocks for each training day; each block of training consisted of a different synonyms deck for each of the 4 days of training on this task. Day-by-day average RCPM data for this task is also plotted in figures 21 through 24.

Participants 2, 3, and 4 showed improvement on the synonyms task overall, whereas Participant 1 showed a somewhat atypical performance as compared to the other participants and tasks. Although Participant 1 started the synonyms task at a higher level than where she started the original and familiar homonyms task, and at only 10 RCPM lower than where she started the letters task, she makes slight decreases in rate for days 2 and 3 of training with only a slight improvement on day 4. Despite the steady decline in her performance on this task, she at no time falls below the highest levels achieved on the last 3 days of training on the original homonyms or the familiar homonyms.

Participant 4 shows the most dramatic progress on this task as she makes a big increase between day 1 and 2, and slight improvement between days 2 and 3, and then another big increase between days 3 and 4. Participant 2 and 3's data show more variability than Participant 1's data, but both of them end the task at a higher level than where they started it.

Patterns of Improvement Across the Training Decks-Sentences

Figures 17 through 20 present data that reveal the effects of direct training on the sentences decks. Each plotted point represents the average of the 15 trials within the same deck, which made up one of the four training blocks for each training day; each block of training consisted of a different sentences deck for each of the 3 days of training on this task. Due to time constraints as well as having 12 decks in the sentences task to train the participants on, it was necessary to train 4 blocks of sentences decks over 3 days of training as opposed to 3 blocks over a specified amount of days as with the other tasks. Day-by-day average RCPM data for this task is also plotted in figures 21 through 24.

All participants show a similar trend of continual progress on the sentences decks, with the exception of Participant 2 whose progress decreases slightly from day 2 to day 3. Although none of the four participants reached performance rates on the sentences task that were comparable with the other tasks, this is likely largely due to the fact that the sentences task required much more reading and comprehension than the other decks.

Training Data compared to the Probe Data

Upon analysis of constant decks in the first probe session data (figures 25 through 28), it is revealed that all four participants started training on the letters, synonyms, and sentences task at a substantially higher levels than achieved on the first probe session (the

probe data will be further discussed below. Participants started training on the letters task at between 15 and 40 points higher, the synonyms task at between 20 and 50 points higher, and the sentences at between 30 and 40 points higher) compared to the corresponding constant deck for each of these tasks.

Although it is possible that the limited exposure to the letters task (20 trials), the synonyms task (50 trials), and the sentences task (50 trials) from the preceding probe sessions may have contributed to this phenomenon, it is also very likely that prior training on the other tasks (240 to 345 trials) allowed the participants to develop a skill or strategy for learning that they were able to transfer to the successive training tasks.

Three explanations for these generalization effects are, 1) generalization of improved performance arose from prior training on the same task, but with different stimulus items, during earlier probe sessions (as noted above), 2) generalization of improved performance arose from prior training on decks from other tasks, or 3) apparent generalization of improved performance arose from training over the first block itself.

When comparing a training block with a previous probe block, the training block RCPM might simply be greater because 15 trials of training is being compared to a mere 5 trials of practice. That is, comparing the first block of training with the previous 5 trials of probe is comparing a mean derived from 15 trials, with all the practice involved, with a mean derived from only 5 trials; clearly this could produce a greater mean score for the 15-trial-based training block mean. However, the RCPM from only first 5 trials of a training block could be compared to the 5 probe trials and then this confound (i.e. more trials being compared to fewer trials) would no longer exist. Therefore, if improvement was seen in training it could not then have been due to the 3rd point raised above,

"...training over the first block itself". Of course, comparing probe trials only to probe trials across the study would also eliminate the difference in the number of trials involved, thus getting rid of the confound of comparing unequal trial numbers. Unfortunately, these comparisons were not made in the present study. However, IF explanation (3) could be discarded as a factor contributing to generalization effects based on the above-mentioned grounds, then explanations (1) and (2) remain.

The question here is, "How do you unconfound factors (1) and (2)"? This is decidedly harder to do than with explanation (3) as every single task that is probed after training on a specific task has also been probed before training on that training task, due to there being an initial probe session before training began. This initial probe session was necessary to determine the initial RCPM levels for each task were before any training in order to serve as a baseline to which subsequent training could be compared. In other words, suppose the synonyms versus antonyms task had been probed for the very first time AFTER the homonyms task was trained and it was found that the initial RCPM was greater for the synonyms versus antonyms task than it had been on the first probe session for the homonyms task. It would be impossible to determine if the greater RCPM achieved on the synonyms versus antonyms task was due to a generalization effect from the homonyms task or whether it was just an "easier" task (i.e. had we tested the synonyms versus antonyms task initially--before the homonyms task--it would also have been comparatively better).

This is a real dilemma. How does one get a measure of pre-training RCPM levels on a task without, at the same time, providing the opportunity for some practice-based improvement which can then generalize to the very next trial on the same or subsequent

training task? It may be possible to get a clearer indication of what is influencing generalization effects (i.e. probe practice versus training effects) by retaining the initial probe session in which all of the tasks would be probed, then in each probe session thereafter only probing the task(s) that was/were trained immediately before that particular probe session; all tasks would be probed once again at the end of the study. This would minimize the amount of trials of practice each participant would receive prior to each subsequent training task due to probe sessions while still providing a baseline measure for all of the tasks as well as an "after each task" measure and an "end of study" measure for comparison.

Another way to try to determine what is causing the generalization effects could be to run the different participants on different probe orders in the first probe session. It could then be verified if those who trained on a given task later (i.e. after other probe sessions) did better than those who were probed on the same task at a different point in their probe order. However, neither of these designs was implemented in the present study, as all of the participants received all of the trained, or to-be-trained, tasks in each probe session in the exact same order.

N.B. Probe session 4 comprised a selected group of decks (a certain number for each task) and these were tested with the participants' right hands. Probe session 5 included the exact same decks as presented in probe session 4, however the participants tested on these with their left hands. Due to this repetition of decks the data for probe sessions 4 and 5 were combined to create averages for each deck tested over the two sessions. Participants were also tested on both their right and left hands in probe 6.

Patterns of Improvement across the Probe Data-The Homonyms Task

Figures 25 through 28 reveal the probe data for all the tasks collectively and figures 29 through 44 present the probe data for all of the tasks individually. Each data point is plotted as the average RCPM for the "constant", "novel", and "trained" decks for each probe session.

In the case of the homonyms task, there is a clear distinction between Participant 1and 4's data and Participant 2 and 3's data. Figures 29 and 41 show that Participants 1 and 4, who trained initially under the same-deck condition, showed the most improvement across decks on the novel homonym task later in their training schedule (i.e. after probe 3), whereas figures 33 and 37 show that Participants 2 and 3, who consistently trained in the variable-deck condition, showed their greatest increases on the homonym task earlier on in training (i.e. after the 1st probe session). This is consistent with the proposition that a more variable training condition fosters greater transfer, as well as Schneider and Fisk's (1984) and Duncan's (1958; 1960) claim that training effects are more likely to generalize if the conditions are varied. On the other hand, there is some evidence at least for a similar difference among these participants with respect to the synonyms and sentences tasks, which either means that this is strictly an individual-difference phenomenon which happened to be confounded with the initial same- versus variable-deck training conditions or that variability, with respect to early homonym training, also impacted on these subsequent tasks. In other words, to take the simplest case, if there were two participants, one (P1) who trained on variable decks and the other (P2) who trained on a single deck over the first 5 training sessions and it was found that P1 showed much more improvement from Probe 1 (pre-training) to the novel homonym decks on Probe 2 (post-training), while

P2 tended to show much greater improvement only by Probe 3 than this would be consistent with the effect of variable training. But of course, the difference between the variable/same conditions is confounded by individual differences in the participants (e.g. if P1 was a "better" participant--one who learns faster than P2). However, the argument that this trend is merely an individual-difference phenomenon--Participant 2 and 3 simply showing an overall tendency to train more effectively--does not seem to be supported by the training data, where the degree of improvement across decks on letters, synonyms, and sentence tasks (figures 21 through 24) actually seems to be greatest for Participant 4.

The constant decks were present in every probe session and therefore got more practice (30 trials) than the training decks (5 trials, as each different training deck only appeared once in probe sessions). This could explain why the constant decks end up as high, or higher than, then training decks. This is consistent with the notion that most of this improvement was due to the limited practice on these decks; the total amount of practice on these decks (5 trials per probe session) would be comparable to the early stages of training which, as discussed earlier, would correspond to the steeper slope in the negatively accelerated performance function

Patterns of Improvement across the Probe Data -Letters

The letters task (figures 33 through 36), for which only one novel deck was available (the limit of 26 letters in the alphabet restricted the number of decks that could be created), showed a clear increase from the first to final probe session. In the final probe session the RCPM values for the novel letters deck were close to, and in some cases as high (Participant 3) or even higher (Participant 4) than those for the constant deck. Further, Participant 2 and 4's novel letter decks were even higher than the trained letters

deck, and Participant 1 and 3's novel letter decks were not significantly lower than the trained letter deck. These data are clearly evidence of generalization effects as the constant deck received a total of 30 trials of practice across the preceding 5 probe sessions, whereas the trained deck received 55 trials of practice (from probe and training sessions), with both shaping and monetary reinforcement, the former which has been shown to enhance practice effects (Grabavac, 1994). The negatively accelerated pattern of improvement across trials, which can produce large increases in performance very early in practice, may make it difficult to estimate the degree of generalization--that is, even a few practice trials on a novel task during a probe session is able to cause large improvements, while subsequent large numbers of training trials may produce only small additional increments.

Patterns of Improvement across the Probe Data-Synonyms

Figures 37 through 40 reveal the participants' performance on the synonyms versus antonyms decks. Participants 1 and 4 showed similar trends on this deck in the probe sessions, in fact, their constant, novel and trained synonyms decks follow almost the exact same pattern, with few variations. Their constant decks start with a big increase from probe 1 to 2, a slight increase from probe 2 to probe 3, and then consistent steady increases from probe 3 to 4/5 to 6. Their novel synonyms decks begin slightly above the constant deck in the first probe, then fall slightly below the constant deck in the second probe, then increase to slightly above the constant deck in the third probe (with Participant 1 showing a more prominent increase). In probe 4/5, Participant 1 shows a slight increase in the novel deck over the constant deck, whereas Participant 4's novel deck remains below the constant deck; however, both their novel decks are below the constant deck on the last

probe session. Both Participant 1 and 4's trained deck begins at the same level as the novel deck and in the final probe is almost exactly in between the novel and constant deck.

Patterns of Improvement across the Probe Data-Sentences

In figures 41 and 44, Participants 1 and 4 once again show a very similar pattern of improvement. In the first probe session Participant 1 begins the novel and training decks at almost the exact same level, which is only slightly above the constant deck. Participant 4 also begins the novel and training decks at almost the exact same level, but starts the constant deck at this level as well. Beyond probe 1, probe sessions 3 through 6 display the same pattern for both participants. That is, the constant deck follows a somewhat negatively accelerated curve, whereas the novel deck always remains slightly below the constant deck until the last probe session where both participants experience a decrease and a wider gap occurs between these two decks. The training deck, as with the synonyms deck, is positioned almost exactly in between the constant and novel deck.

Participants 2 and 3 also share a similar pattern of improvement with each other, and have some elements in common with Participants 1 and 4; however, they show much more variability on the novel deck. Participant 2's constant deck starts almost 10 points higher than the novel deck, whereas Participant 3's constant deck starts almost 10 points lower than the novel deck; both their training decks start at the same level as the novel deck. From probe 2 to probe 6 their novel decks, as with Participant 1 and 4, remain below the constant deck, yet with more highs and lows. That is, with the novel deck from probe 2 to probe 3 they both experience a decrease, then from probe 3 to probe 4/5 they experience an increase, then from probe 4/5 to probe 6 they experience another decrease. Participant 2's training deck ends at a level almost 10 points higher than where the constant

deck ended, whereas, like Participant 1 and 4, Participant 3's training deck ends almost exactly between the constant and novel deck.

Probe Data-All four tasks

Overall, across all four participants and all four tasks, a similar pattern, with some variability, is revealed. The constant deck tends to show the most consistent improvement, which is expected as the same deck is repeated in all sessions; the novel deck remains below the constant deck, which is dually expected as it was a completely new deck for each probe session and did not share the same repeated exposure as the constant deck; and, the trained deck ends up somewhere between the constant and novel deck, this result is also not a surprise as, even though it had been trained, it still only received 15 trials of training, whereas the constant deck received 25 trials of training by the last probe session. However, as mentioned, some variability from this pattern did occur. At points, participants did as well as, or better than, the constant with the novel deck, which might be an indication of transfer effects as it can not be attributed to prior exposure or practice on the deck. Any improvement across the probe sessions on the novel decks is a definite indication of generalization since each of these decks was indeed novel.

Did Training Effects Transfer Across Tasks?

Figures 21 through 24 (which present the average RCPM for each three-block training day for each task) and figures 29 through 44 (which present the average RCPM for the "constant", "novel", and "trained" decks for each probe session) show evidence that improvements due to training did generalize across the different tasks used in training.

When comparing initial probe data (Figures 25 through 28) with the training data for all 4 tasks (figures 21 through 24) it is revealed that subsequent training tasks showed

RCPM values that were much higher than in their initial probe session after only minimal, or no exposure at all, to training or practice effects. But, as above, these involve comparisons of 15 trials on the first training block with only 5 on the initial probe block.

Figures 29 through 32 and 41 through 44 show further evidence that generalization occurred across tasks. Both novel synonyms (figures 37 through 40) and novel sentences (figures 41 through 44), which were not trained until after the fourth and fifth probe session, respectively, showed at least some definite improvement across probe sessions prior to being trained. However, this might be due to generalization from prior practice during probe sessions or on the other synonyms and sentences decks and might not be generalization from the other tasks.

Are Variations in Deck Difficulty Responsible for Discrimination Speed Improvement?

As mentioned in the procedure section, we tried to minimize the degree to which each participant's performance would be influenced by the occurrence of deck effects with respect to decks of varying difficulty. The data do demonstrate that deck effects are not likely responsible for the participants performance.

For example in figures 1-4, the homonym decks H08 and H09 occurred in all four participants training schedules at different points and there is no clear pattern suggesting that one was easier or harder than the other. Deck H08 was positioned before deck H09 in Participant's 1 and 2 training schedule (separated by 7 and 5 other decks consecutively), whereas deck H09 was positioned before H08 in Participant's 3 and 4 training schedule (separated by 5 and 7 decks consecutively). Yet, for all four participants, the deck that was positioned first was lower than the deck that was positioned later. This phenomenon holds true for most of the decks presented to the participants, across the different tasks, in

their training schedules thus controlling the effects of the order of difficult versus easier decks as the explanation of their performance improvements.

Was Generalization Due Merely to Improvement in Motor Skills?

Figures 45 through 48 and 49 through 52 show the rates for right and left-handed performance for the fifth and sixth probe sessions consecutively. As mentioned above, in these probe sessions the participants ran through the same set of decks with their right hand and then, for the very first time, their left hand. The left-handed probe data were comparable to, and generally higher than, the right-handed probe data for each of the decks, for each task. In fact, the vast majority of the trials (69% to 100%) were in fact faster with the left hand than with the right hand. Although it could be suggested that the faster performance on the left hand trials benefited from immediately following right hand trials and was, therefore, due to a nonspecific effects (e.g. familiarity and practice with the deck items), it is clear that an almost complete transfer of skills occurred from the trained to untrained hand. Pashler and Baylis (1991) found similar results when they had their participants switch from training with their dominant hand to their non-dominant hand in on the tasks mentioned in their study above. These factors consequently confirm that the participants' motor skills could not be the sole basis of the generalization seen in this study.

Further, for the simple movements involved in button pressing, the participants had likely learned equivalently fast responses, or S-R relations, in many every day settings (e.g. dialing a phone). Therefore, if improvement in performance was NOT due to sheer motor practice, but rather to the actual discriminations, the hand that each participant used to make the button presses would not make a difference. To put it another way, suppose

"CORRECT" was the desired covert response and the stimulus controlling this response (S^D) was "PRESS KEY MARKED CORRECT". If improved performance reflects the relation between the stimulus (e.g. large-big, in the case of the synonyms versus antonyms task) and the covert response, "CORRECT", rather than between the covert stimulus, "CORRECT", and the response, "PRESS KEY MARKED CORRECT", then it would be expected that participants would perform equally well with both hands due to the factors influencing responding.

Conclusions and Suggestions for Future Studies

Possible Reasons for the Demonstrated Generalization

The data show that training across various decks, within the specific tasks, promoted an improvement in speeded discrimination performance and that this improvement generalized to other decks within each task. Further, the data indicate that this generalization was not due solely to practice effects from probe sessions, or to simple improvement in motor skills.

Learning to Learn

Based on these results, we can conclude that this generalization is not confined to the transfer of skills between trials in a particular training deck. From the data, it appears evident that a simple generalization of speedy response times from trained to untrained stimuli can not handle this without relying on some mediating response to bridge between one set of stimuli and another, since physically the stimuli have little in common. If the participants are learning to learn, what this means is that the participants are actually learning to make the stimulus discriminations more quickly on subsequent tasks due to prior training. Learning to learn is the experience of acquiring the skills of learning

through practice with the result being relatively permanent changes in behaviour (Postman, 1972). Further, evidence shows that continual exposure to a given paradigm can lead to an increase in performance at the transfer stage, (Woodworth & Schlosberg, 1954).

Neural Processes: Activation Patterns

Another possible way to interpret these data is suggested by Donahoe and Palmer's (1994, pp. 240-243) discussion on activation patterns. Their textbook definition of an activation pattern is "a widespread pattern of neural activity in the brain, initiated by stimuli applied to the receptors of an experienced learner" and that "an activation pattern meets the criteria for a behavioral response in that it is guided by the environment and affected by its consequences and is directly observable only at the neural level of experimental analysis". This notion supports Lashley's (1942, p. 771) statement that "when any complex of stimuli arouses nervous activity...certain elements or components become dominant for reaction while others become ineffective".

Donahoe and Palmer assert that changes occur in the synaptic efficacies in the motor areas of the brain due to a history of behavioral selection, and that "inputs to the motor areas of the brain...can recruit a motor component of the activation pattern if environment-behavioral relations have been previously selected in the presence of stimuli that activate the stimulus component" (Donahoe & Palmer, 1994, p. 241). They say that individual neurons within activation patterns can be measured by microelectrodes, while a Positron-Emission Tomography (PET), which measures emission of particles released through the metabolism of glucose in the brain cells, is used to measure the pattern as a whole. Through pictorial examples, Donahoe and Palmer (1994) provide reconstructions

of PET scans that show an effect in the brain of the accumulated "meaningfulness" of an English word (i.e. one that has been associated, for example, with responding overtly in certain ways, such moving toward a person when they say "Come here"). The "meaningful" word, but not other non-English sounds, elicited activated areas in the motor association cortex as well as in the primary auditory and auditory association cortices.

Further, they suggest that OVERLAPPING activation patterns can be used to interpret priming effects; that is, when a subject learns a list of paired-associates composed of items such as "27-tacks" and is later asked to learn a second list with the same stimuli but with different responses. It has been found that the new responses are learned more rapidly if they evoke similar vocal responses (e.g., "27-tax"), (Donahoe & Palmer, 1994). Similarly, if the responses are similar in meaning (e.g. "sofa" and "loveseat") they also are more readily learned. Donahoe and Palmer (1994) interpret this facilitation of retention as an effect of overlap in the activation patterns evoked by the stimulus items. For example, if a participant learned "32-sofa" and then was required to learn "32-loveseat", one could hypothesize that the participant would do better on the latter because "32" activates -via responses to the word "sofa"-- some of the same neurons underlying the response "loveseat". Therefore, some of the neurons necessarily associated with the stimulus "32" in the second task have in effect already been associated neuronally as an activation pattern.

The possibility that the history of responding in similar ways (e.g. "correct" to properly used homonyms, matching letter pairs, synonym pairs and good use of grammar and "incorrect" to improperly used homonyms, non-matching letter pairs, antonym pairs and bad use of grammar) might not only create common activation networks within each

task, allowing new stimuli to then become linked to them, but even provide a mechanism for cross-task transfer. As the participants in our study began to respond in the same way (i.e. on the keys on the button box labeled as either "correct" or "incorrect") to stimuli in task B, as they had already responded to stimuli in task A, the functionally equivalent within-task stimulus items came under the control of these new, "high-speed" S-R relations (e.g. "cold- freezing" = rapid "correct" key response readily transfers to "hot-boiling") because of the stimuli's history of a common "correct" response. After the participants had responded to many examples of "correct" and "incorrect" stimuli from each task on the same "correct" and "incorrect" keys on the response box, the common set of neuronal networks involved could have began to mediate transfer across the tasks.

Covert and Overt Responses: Shorter Latencies

Generalization effects are governed by the nature of the learned behavior that is generalizing. When generalization of fluency occurs, the latencies between the presentation of stimuli and the consequent responses of subsequent training tasks get shorter; in other words, the participants "get faster." But what is it that mediates these faster responses or shorter latencies? In a personal communication with Dr. Bram Goldwater (January 26th, 2000) he explained four ways in which latencies might become shortened in terms of what is occurring with both the covert response (i.e. unobservable-neural-sensory/motor processes) and the overt response (i.e. observable-pressing a button on the button box) in training, and the subsequent effects in testing to novel stimuli.

1) In training: the covert response remains the same, but the overt response becomes faster (e.g. S-->COVERT R--**faster**-->OVERT R). In testing: this leads to a shorter latency between the stimulus presentation and the button press. With this type of transfer

the covert response, which is unobservable, is not the cause of the improvement in speed. It is likely the common overt responses (e.g. "correct" button press for "synonym") that are required for each task becomes over-learned and subsequently leads to shorter latencies. Therefore, the participants are not learning to continually make new responses, but are learning to make an old response more quickly.

2) In training: the covert response becomes faster, but the latency between the covert response--or it's "stimulus consequences" and the overt response remains the same (e.g. S--**faster**-->COVERT R-->OVERT R). In testing: If the interval between S and COVERT R is shorter, so will the observable interval between S and OVERT R--it doesn't matter which link speeds up). The covert response's speedier occurrence allows the overt R to be triggered earlier; because of this, this type of transfer would likely transfer across hands

3) In training: both the covert response and overt response becomes faster (e.g. S--**faster**-->COVERT R--**faster**-->OVERT R). In testing: this might lead to a partial decrease in latency, and generally follows the same reasoning as stated above in 2.

4) In training: the covert response is completely bypassed and the overt response occurs "automatically" (e.g. S-->OVERT R). In testing: this type of responding learned in training would not be transferred to novel stimuli in testing due to the presumed mechanisms underlying traditional stimulus generalization (as discussed above with respect to stimulus equivalence) and therefore, there would not be a change in latency. However, this is only true if the COVERT R is the only link between S and OVERT R. If the stimuli from different decks or tasks share some other common relation(s), these could also come to mediate this effect

How does the Data Complement Work done in the Field of Precision Teaching?

As mentioned above, Precision Teachers and their students constantly modify their aims for each task at hand, while striving to achieve fluency by maintaining fast and accurate progress on each task, and then graphing their results in order to set future goals and assess past performance. The data presented in this paper support the wisdom of continuously adjusting the criteria of a task, encouraging fluent performance, and graphing results daily in order to promote better performance. Participants expressed that their direct involvement in setting their own goals and graphing their daily performance provided a stronger motivation to meet subsequent goals than any monetary reinforcement did.

How does the Data Complement the CRT Research Paradigm?

Some researchers have used the CRT paradigm in order to promote fluency and test for generalization effects with much success, the author's previous and present work included. The data in this study support the use of a CRT paradigm, which, as mentioned above, involves participants making speedy, discriminative choices with respect to stimuli, presented individually and randomly on the computer screen, and having only one correct response being reinforced.

By requiring participants to respond quickly and discriminatively to stimuli and recording their reaction times, we have found that it is possible to promote faster and faster reaction times on individual decks in a training session for a particular task, and in some cases, even across training sessions to other tasks.

How does the Data Complement the Generalization Literature?

Duncan (1958; 1960), Stokes and Baer (1977), Schneider and Fisk (1984), and

Ericsson and Charness (1994), to name a few, all suggest that training on a variety of tasks, as opposed to training one or two specific tasks to perfection, is the best way to maximize generalization to novel tasks.

This notion is supported by the data in the present study, as training in the variable-deck condition produced more stable and consistent performance than the constant-deck condition. Participants in the variable deck throughout the study adapted more readily to subsequent decks, while participants who started the study in the constant deck condition showed slower progress, and even decreases in performance, when initially switched to the variable-deck condition. However, they both displayed performance similar to the other two participants once they adapted to the new condition.

Further, the data support that, even with far more difficult discriminations than in such previous studies as, for example, that of Pashler and Baylis (1991), generalization will occur in situations of diverse stimulus discriminations, not only within a particular task, but perhaps across different tasks as well.

Looking to the Future

There is evidence that the ability to make speedier discriminations, following CRT training, transfers to new exemplars within the trained tasks. As mentioned above, there is evidence for transfer effects across tasks that might be accountable in terms of within-task generalization, due to probe session exposure. With this in mind, it might be reasonable to include one or two novel, never-seen-before, tasks in the final probe session in future studies of this kind in order to address the "across-task generalization" issue more clearly.

Unfortunately, this means that one would have no way of estimating what performance on these new tasks would have been like without training on the prior tasks

and this might require a between-subjects design. As discussed in detail above, under *Training Data compared to the Probe Data*, it might be helpful to implement one of two designs in order to better determine what is influencing generalization effects. For the reasons outlined above, future researchers could retain the initial probe session, in which all of the tasks would be probed, then include only the task(s) that was/were trained immediately before that particular probe session in each probe session thereafter, and then probing all of the tasks once again at the end of the study. The second design suggestion would be to implement different probe orders for each participant; that is, all participants would be probed on the separate tasks at different points in the probe sessions.

To completely avoid the issue of faster finger motor responses being responsible for generalization, future research could employ software which would allow the researcher to set up the training/testing paradigm to accept vocal answers to the stimuli presented, as opposed to finger presses on a response box. However, this might also pose problems as speaking is also a motor response and might exhibit the same effects to training as our participants hands did; that is, the participants' speaking would likely become more speedy over time and training.

It seems clear that further research in the area of fluency-based training and generalization, namely with respect to Precision Teaching applications, is a desirable goal for future researchers. Building on the foundation of the findings and results demonstrated in the relevant literature, as well as studies such as this one, researchers might open new doors to fluency-based training and expand the range of generalization that might be achieved.

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Appendix A
Correct and Incorrect Exemplars

Homonym Phrases:

Correct: He made the bed
Correct: They hired a maid.

Incorrect: He maid the bed.
Incorrect: They hired a made.

Letters:

Correct: A a
Correct: i I

Incorrect: A i
Incorrect: a I

Synonyms vs. Antonyms:

Correct: far distant (synonyms)
Correct: cold chilly (synonyms)

Incorrect: far close (antonyms)
Incorrect: cold hot (antonyms)

Sentences:

Correct: He walked down to the corner store.
Correct: She rode her bike because it was a sunny day.

Incorrect: He walk down to the corner store.
Incorrect: She rode her bike because it was a sunny days.

Appendix B
Participant Training Order

Day	Participant 1	Participant 2	Participant 3	Participant 4
Feb. 8	***PROBE 1***	***PROBE 1***	***PROBE 1***	***PROBE 1***
Original Homonyms	**Original Homonyms**	**Original Homonyms**	**Original Homonyms**	**Original Homonyms**
Feb. 9	H07/H07/H07	H07/H11/H13	H16/H14/H12	H07/H07/H07
Feb. 10	H07/H07/H07	H15/H17/H19	H10/H29/H27	H07/H07/H07
Feb. 11	H07/H07/H07	H21/H23/H25	H25/H23/H21	H07/H07/H07
Feb. 12	H07/H07/H07	H27/H29/H10	H19/H17/H15	H07/H07/H07
Feb. 15	H07/H07/H07	H12/H14/H16	H13/H11/H07	H07/H07/H07
Feb. 16	***PROBE 2***	***PROBE 2***	***PROBE 2***	***PROBE 2***
Feb. 22	H08/H10/H11	H08/H18/H20	H30/H28/H09	H09/H16/H15
Feb. 23	H12/H13/H14	H22/H24/H26	H26/H24/H22	H14/H13/H12
Feb. 24	H15/H16/H09	H09/H28/H30	H20/H18/H08	H11/H10/H08
New Homonyms	**New Homonyms**	**New Homonyms**	**New Homonyms**	**New Homonyms**
Feb. 25	N01/N02/N03	N02/N04/N06	N18/N16/N14	N09/N08/N07
Feb. 26	N04/N05/N06	N08/N10/N12	N12/N10/N08	N06/N05/N04
Mar. 1	N07/N08/N09	N14/N16/N18	N06/N04/N02	N03/N02/N01
Mar. 2	N10/N11/N12	N20/N22/N24	N23/N21/N19	N24/N23/N22
Mar. 3	N13/N14/N15	N01/N03/N05	N17/N15/N13	N21/N20/N19
Mar. 4	N16/N17/N18	N07/N09/N11	N11/N09/N07	N18/N17/N16
Mar. 5	N19/N20/N21	N13/N15/N17	N05/N03/N01	N15/N14/N13
Mar. 8	N22/N23/N24	N19/N21/N23	N24/N22/N20	N12/N11/N10
Mar. 9	***PROBE 3***	***PROBE 3***	***PROBE 3***	***PROBE 3***
Letters	**Letters**	**Letters**	**Letters**	**Letters**
Mar. 10	L03/L04/L05	L04/L05/L03	L03/L05/L04	L05/L03/L04
Mar. 11	L03/L04/L05	L04/L05/L03	L03/L05/L04	L05/L03/L04
Mar. 12	L03/L04/L05	L04/L05/L03	L03/L05/L04	L05/L03/L04
Mar. 15	***PROBE 4 Right hand***	***PROBE 4 Right hand***	***PROBE 4 Right hand***	***PROBE 4 Right hand***
Mar. 15	***PROBE 5 Left Hand***	***PROBE 5 Left Hand***	***PROBE 5 Left Hand***	***PROBE 5 Left Hand***
Synonyms	**Synonyms**	**Synonyms**	**Synonyms**	**Synonyms**
Mar. 16	S06/S07/S08	S07/S09/S11	S16/S14/S12	S17/S16/S15
Mar. 17	S09/S10/S11	S13/S15/S17	S10/S08/S06	S14/S13/S12
Mar. 18	S12/S13/S14	S06/S08/S10	S17/S15/S13	S11/S10/S09
Mar. 19	S15/S16/S17	S12/S14/S16	S11/S09/S07	S08/S07/S06
Sentences	**Sentences**	**Sentences**	**Sentences**	**Sentences**
Mar. 23	G06/G07/G08/G09	G07/G09/G11/G13	G16/G14/G12/G10	G17/G16/G15/G14
Mar. 24	G09/G10/G12/G13	G15/G17/G06/G08	G08/G06 G17/G15	G13/G12/G11/G10
Mar. 25	G14/G15/G16/G17	G10/G12/G14/G16	G13/G11/G09/G07	G09/G08/G07/G06
Mar. 26	***PROBE 6 Right/Left Hand***	***PROBE 6 Right/Left Hand***	***PROBE 6 Right/Left Hand***	***PROBE 6 Right/Left Hand***

Appendix C
Figure Numbers and Titles

Figure Number		Figure Title
1.	Figures 1-4	Training Session Rates for Original Homonyms
2.	Figures 5-8	Training Session Rates for Familiar Homonyms
3.	Figures 9-12	Training Session Rates for Letters
4.	Figures 13-16	Training Session Rates for Synonyms
5.	Figures 17-20	Training Session Rates for Sentences
6.	Figures 21-24	Average Training Day Rates over Tasks
7.	Figures 25-28	Probe Session Rates for Six Probe Sessions
8.	Figures 29-32	Probe Session Averages for the Homonym Decks
9.	Figures 33-36	Probe Session Averages for the Letter Decks
10.	Figures 37-40	Probe Session Averages for the Synonym Decks
11.	Figures 41-44	Probe Session Averages for the Sentences Decks
12.	Figures 45-48	Probe Session 4 and 5 Rates for the Right and Left Hand
13.	Figures 49-52	Probe Session 6 Rates for the Right and Left Hand

Appendix D

The following series of graphs (5 per participant) illustrate the daily Training Session Rates for the Original Homonyms, Familiar Homonyms, Letters, Synonyms, and Sentences for each participant. Each plotted point represents the rate correct per minute (RCPM) averaged over 15 trials for each training block, with 3 blocks per daily training session.

Figure 1 Training Session Rates for Original Homonyms
Participant 1: Same/Variable Deck Condition
Each Point represents the rate correct per minute (RCPM) averaged over 15 trials for each block, 3 blocks per session.

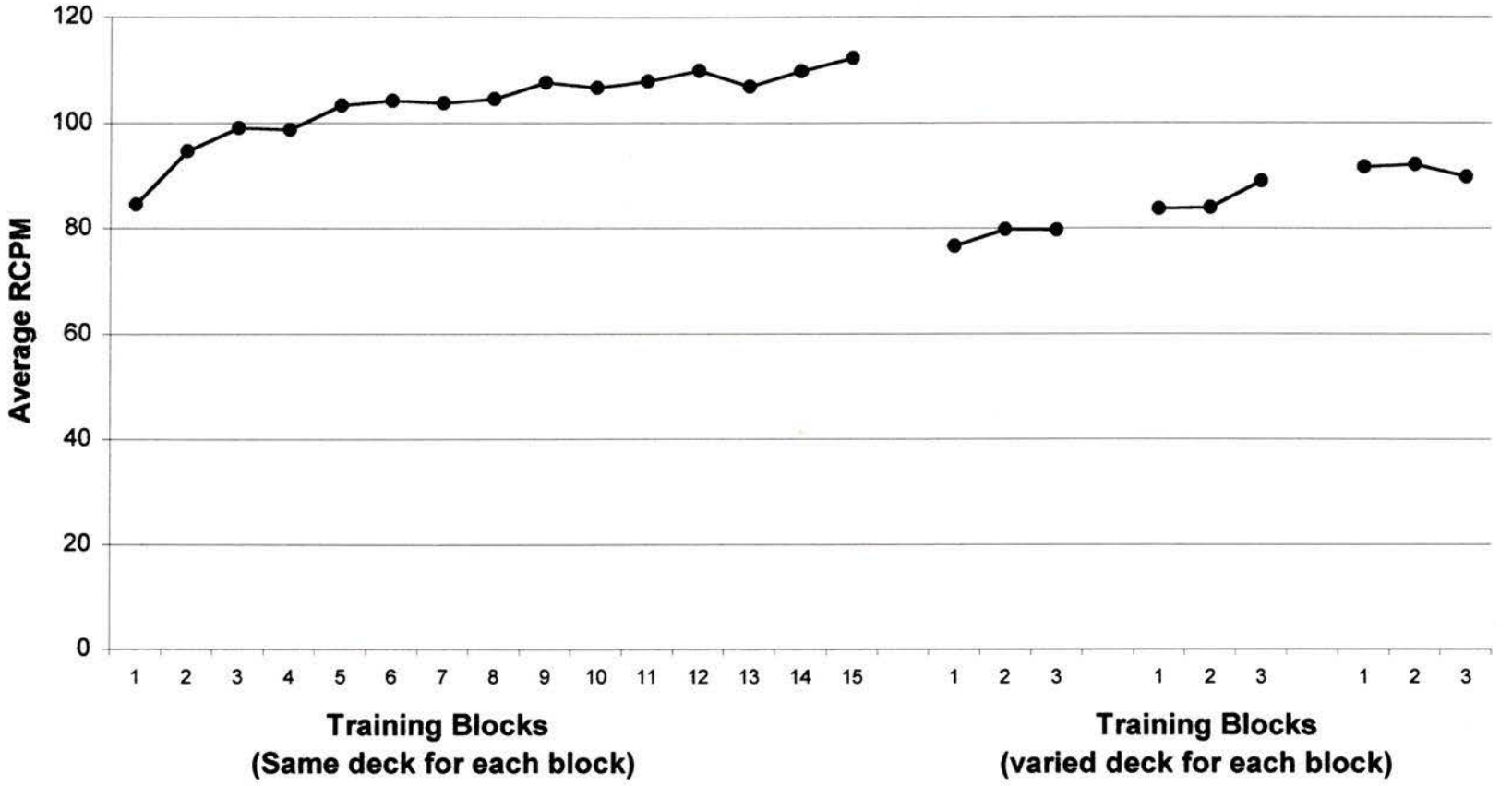


Figure 2 Training Session Rates for Original Homonyms
Participant 2: Variable Deck Condition
Each Point represents the Rate Correct Per Minute (RCPM) averaged over 15 trials for each block, 3 blocks per session.

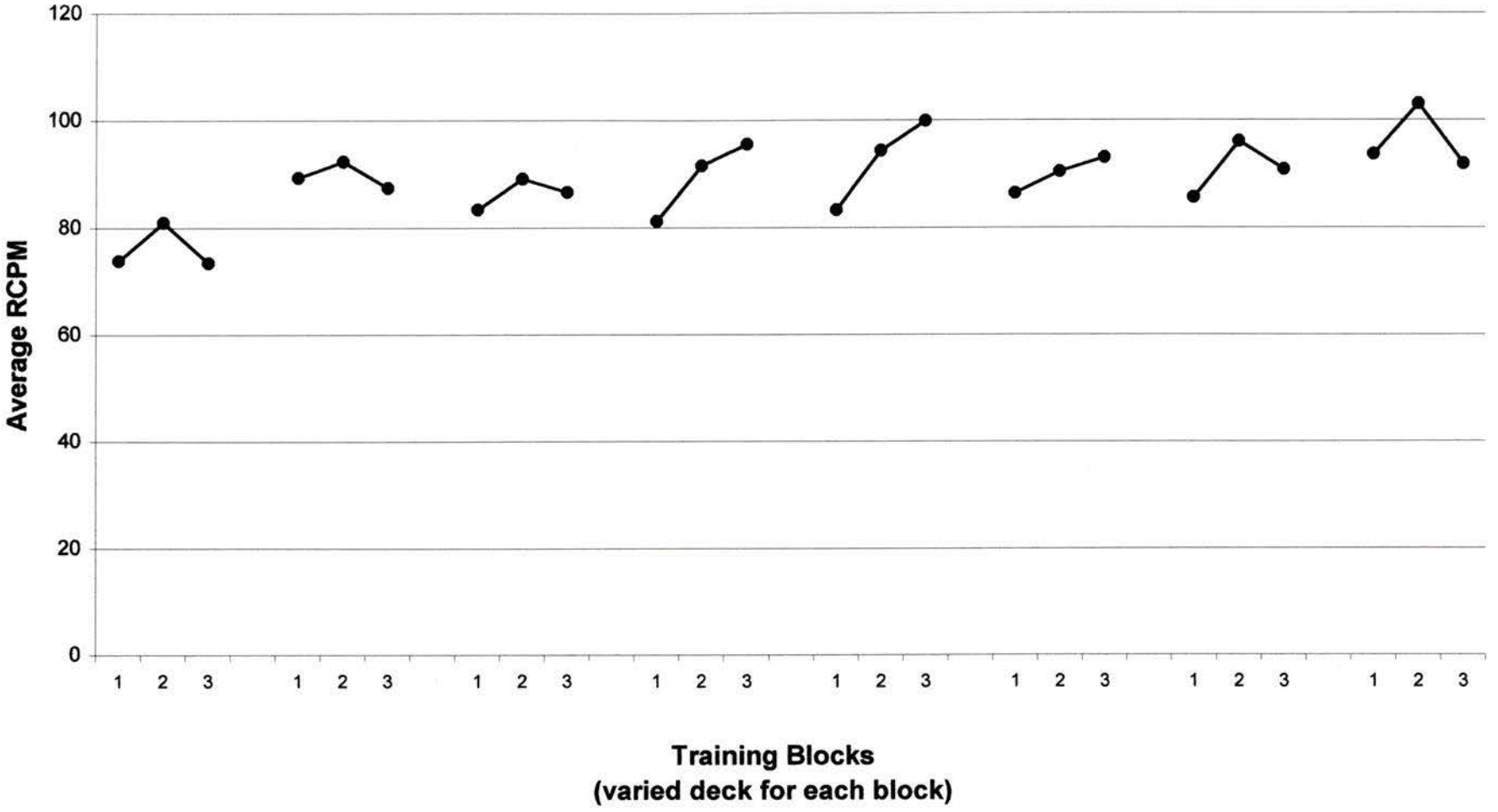


Figure 3 Training Session Rates for Original Homonyms
Participant 3: Variable Deck Condition
Each Point represents the Rate Correct Per Minute (RCPM) averaged over 15 trials for each block, 3 blocks per session.

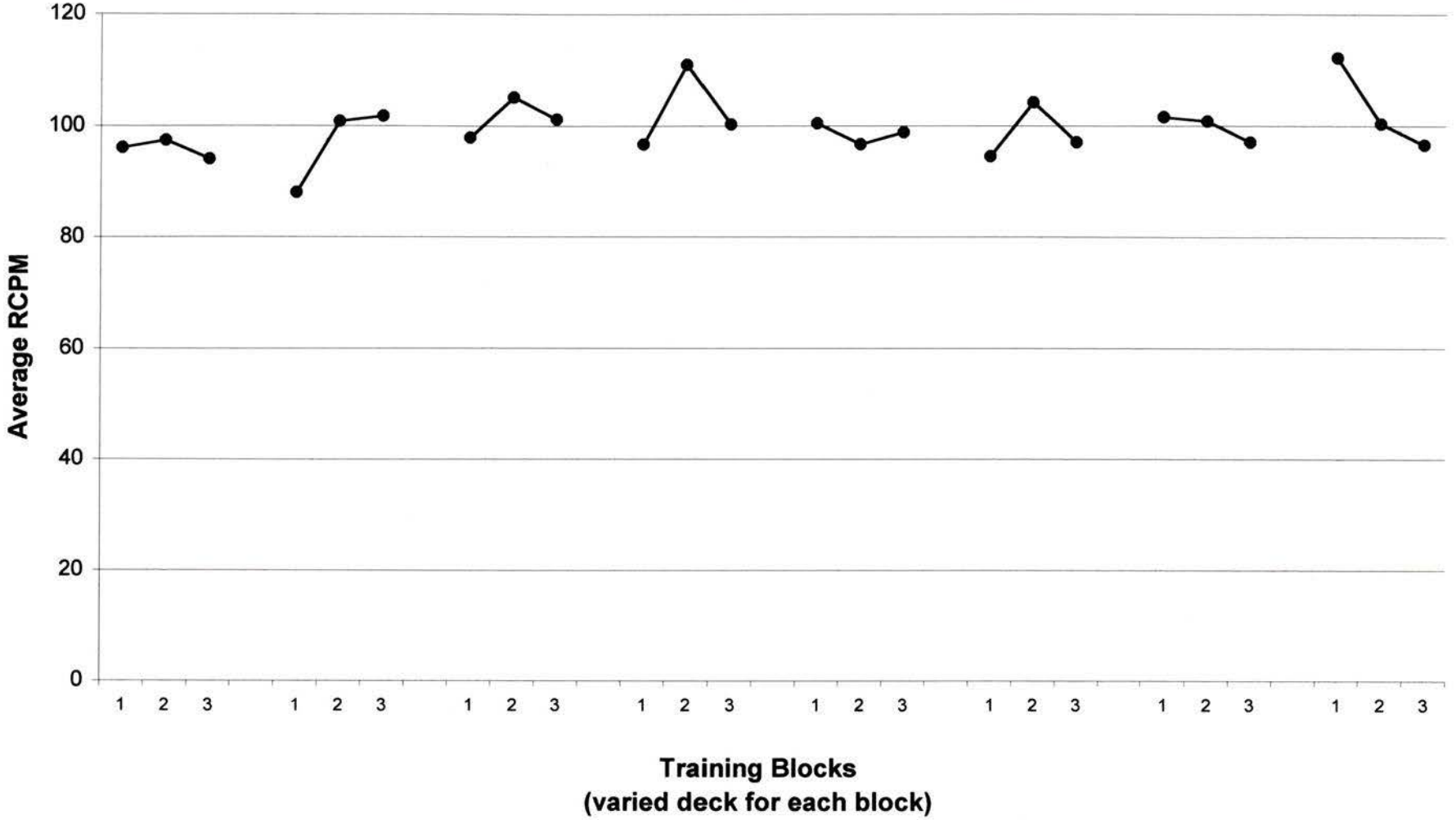


Figure 4 Training Session Rates for Original Homonyms
Participant 4: Same/Variable Deck Condition
Each Point represents the rate correct per minute (RCPM) averaged over 15 trials for each block, 3 blocks per session.

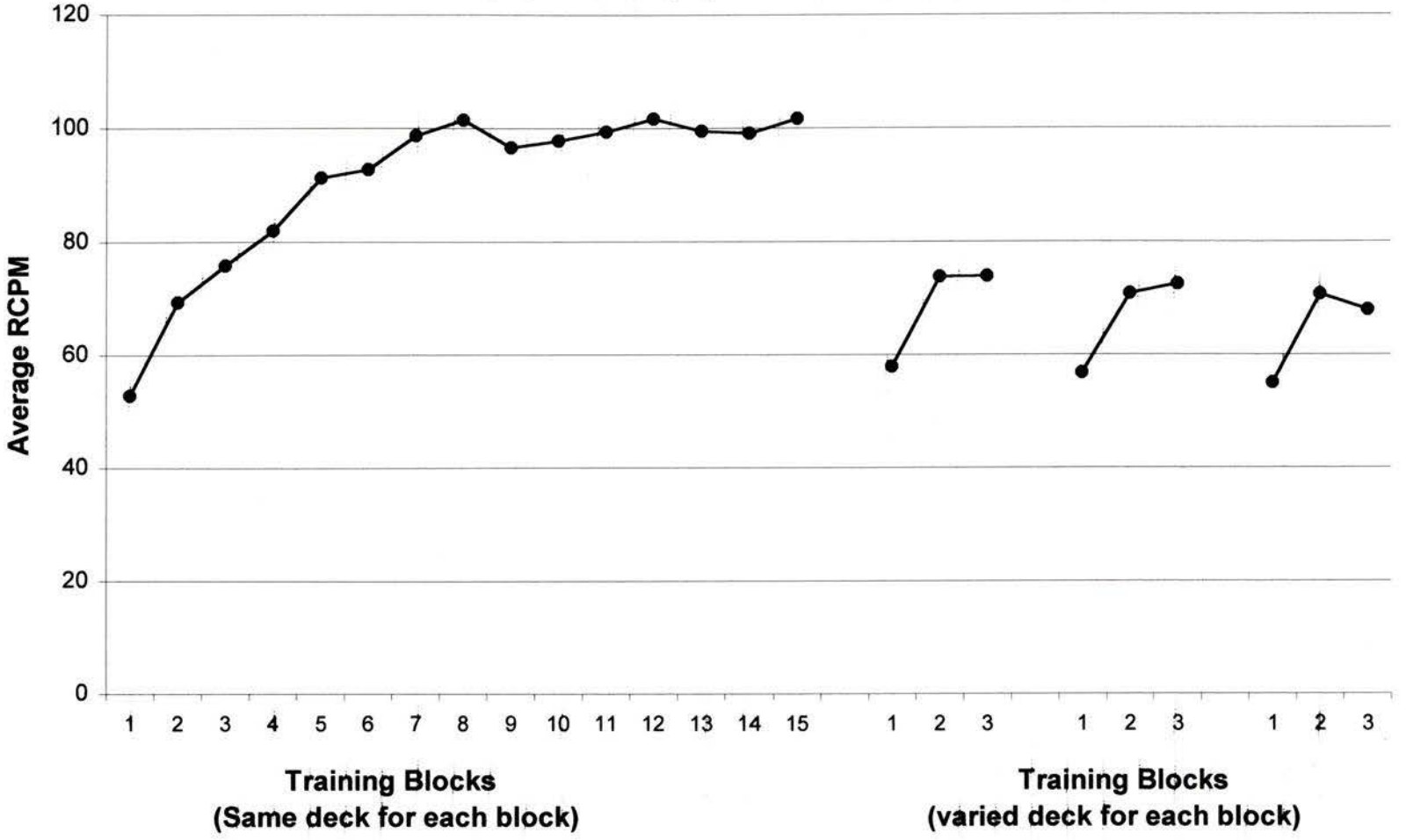


Figure 5 Training Session Rates for Familiar Homonyms
Participant 1: Variable Deck Condition
Each Point represents the RCPM averaged over
15 trials for each block, 3 blocks per session.

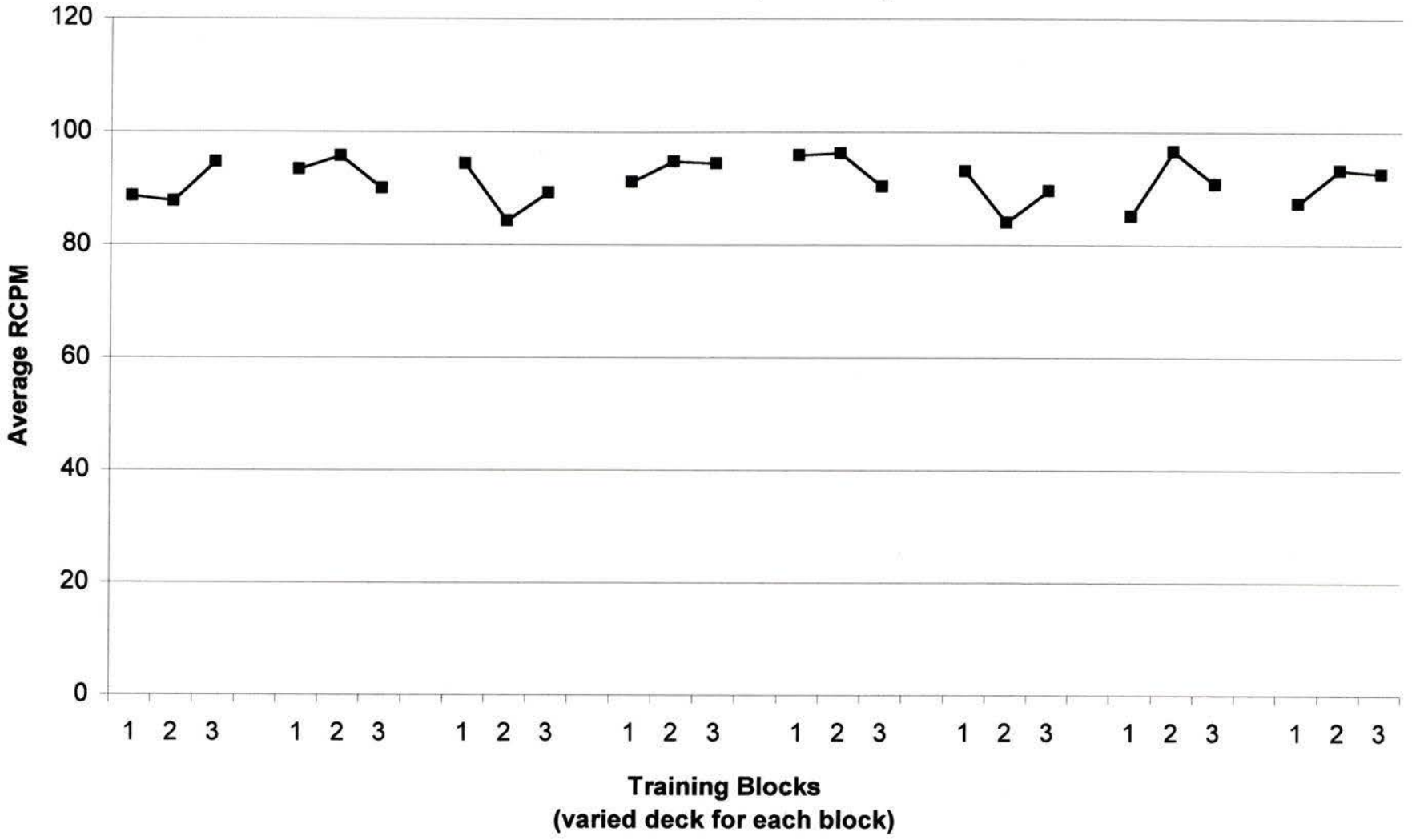


Figure 6 Training Session Rates for Familiar Homonyms
Participant 2: Variable Deck Condition
Each Point represents the rate correct per minute (RCPM) averaged over 15 trials for each block, 3 blocks per session.

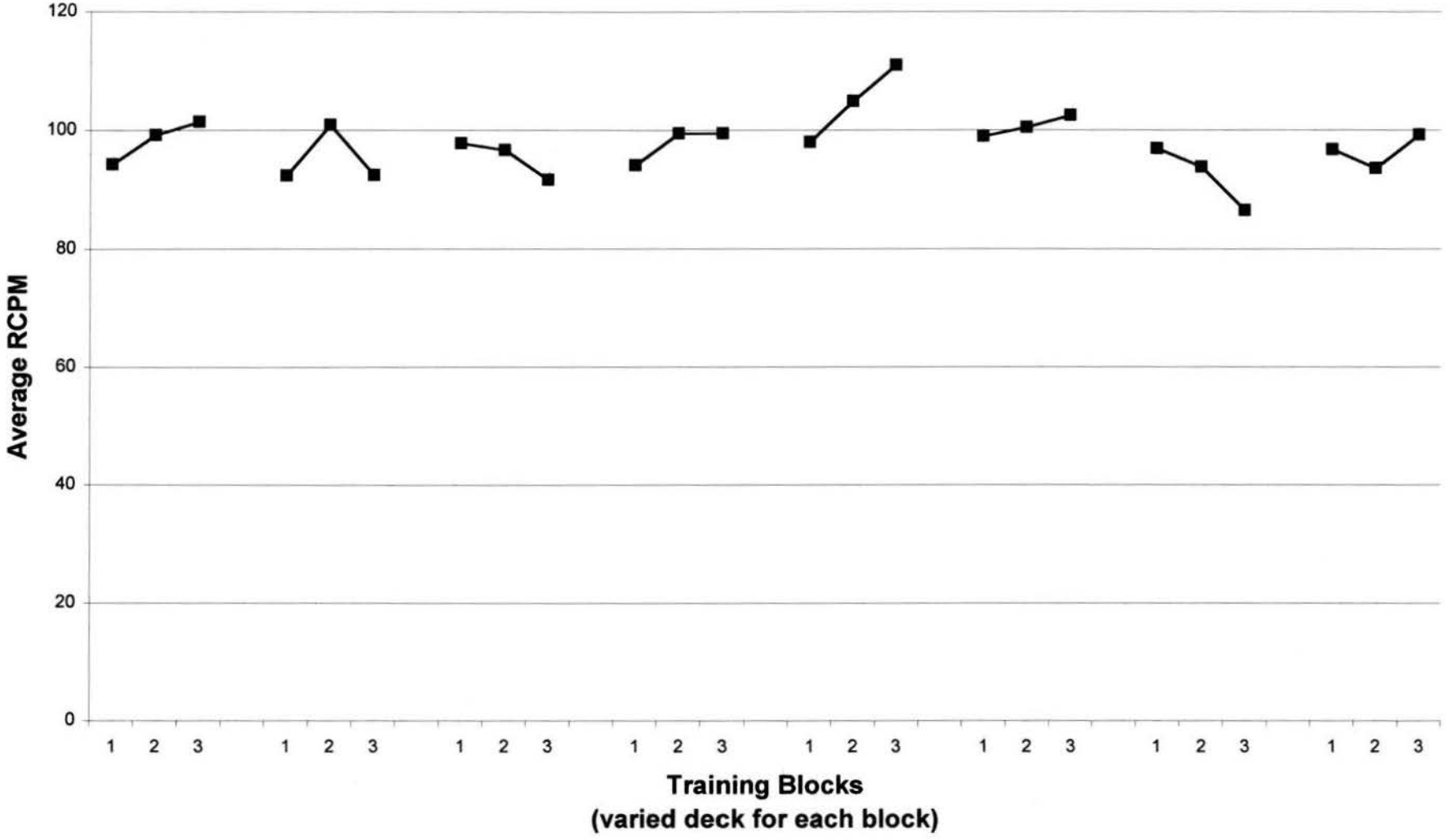


Figure 7 Training Session Rates for Familiar Homonyms
Participant 3: Variable Deck Condition
Each Point represents the Rate Correct Per Minute (RCPM) averaged over 15 trials for each block, 3 blocks per session.

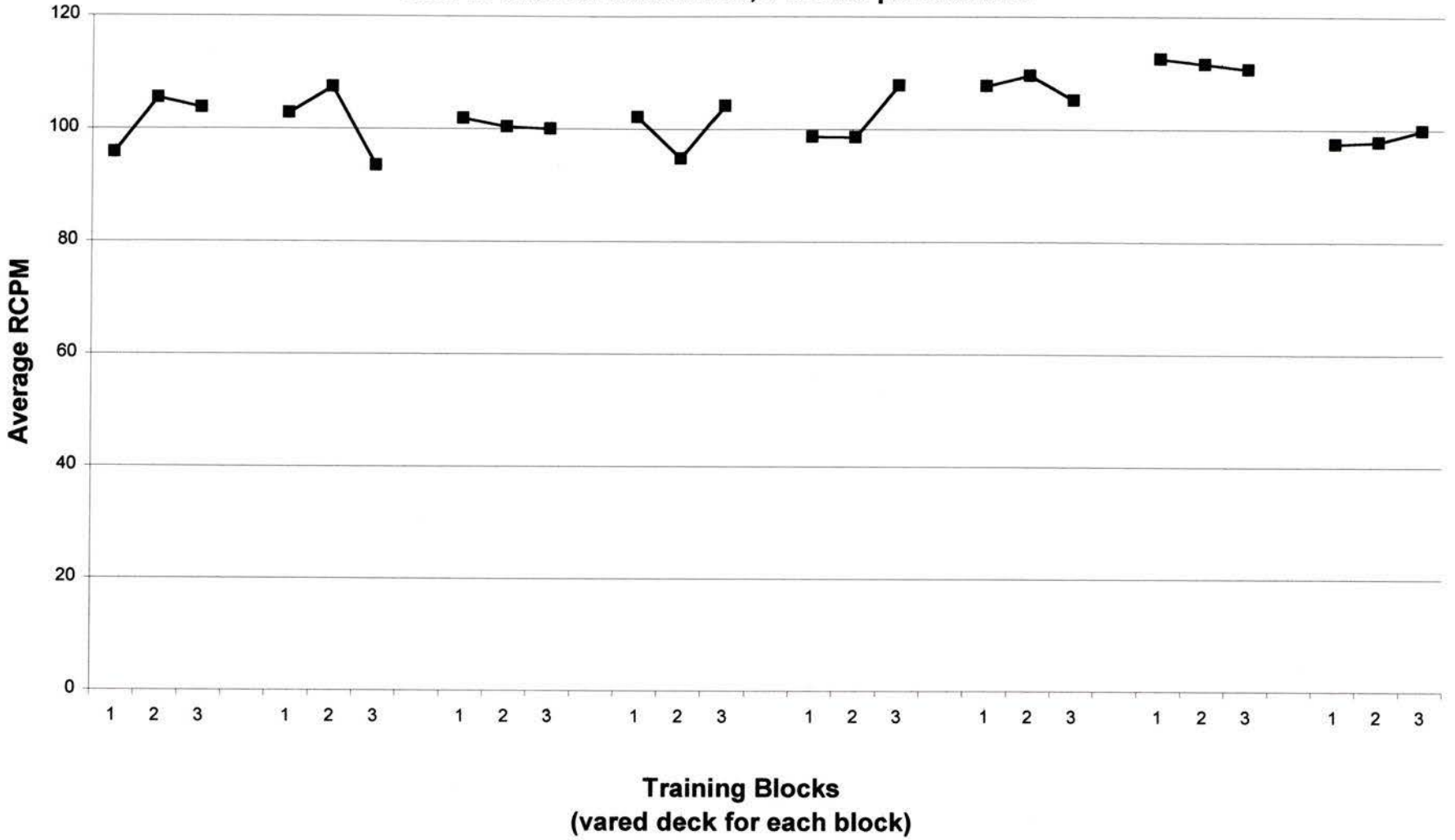


Figure 8 Training Session Rates for Familiar Homonyms
Participant 4: Variable Deck Condition
Each Point represents the RCPM averaged over
15 trials for each block, 3 blocks per session.

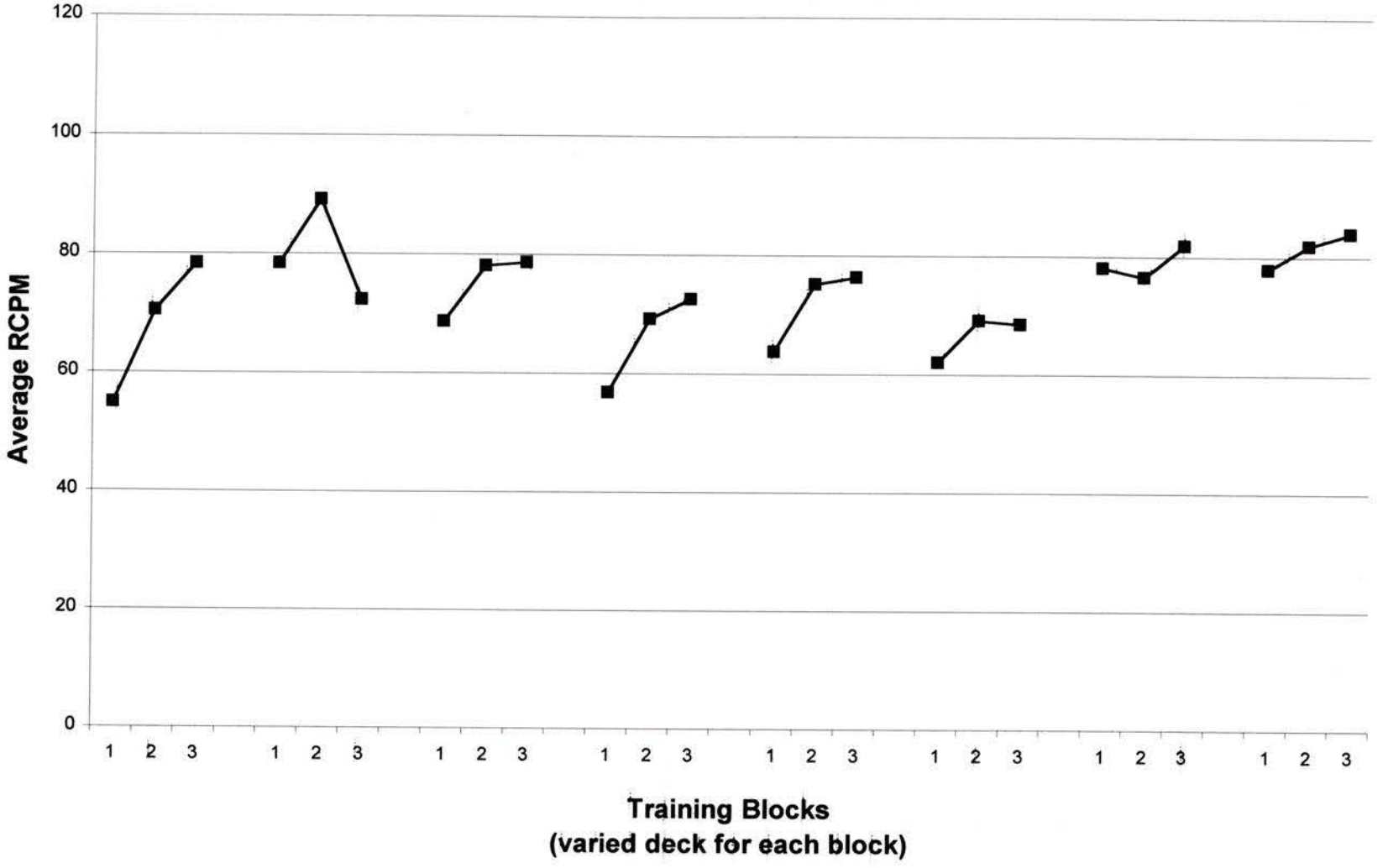


Figure 9 Training Session Rates for Letters
Participant 1: Variable Deck Condition
Each Point represents the RCPM averaged over
15 trials for each block, 3 blocks per session.

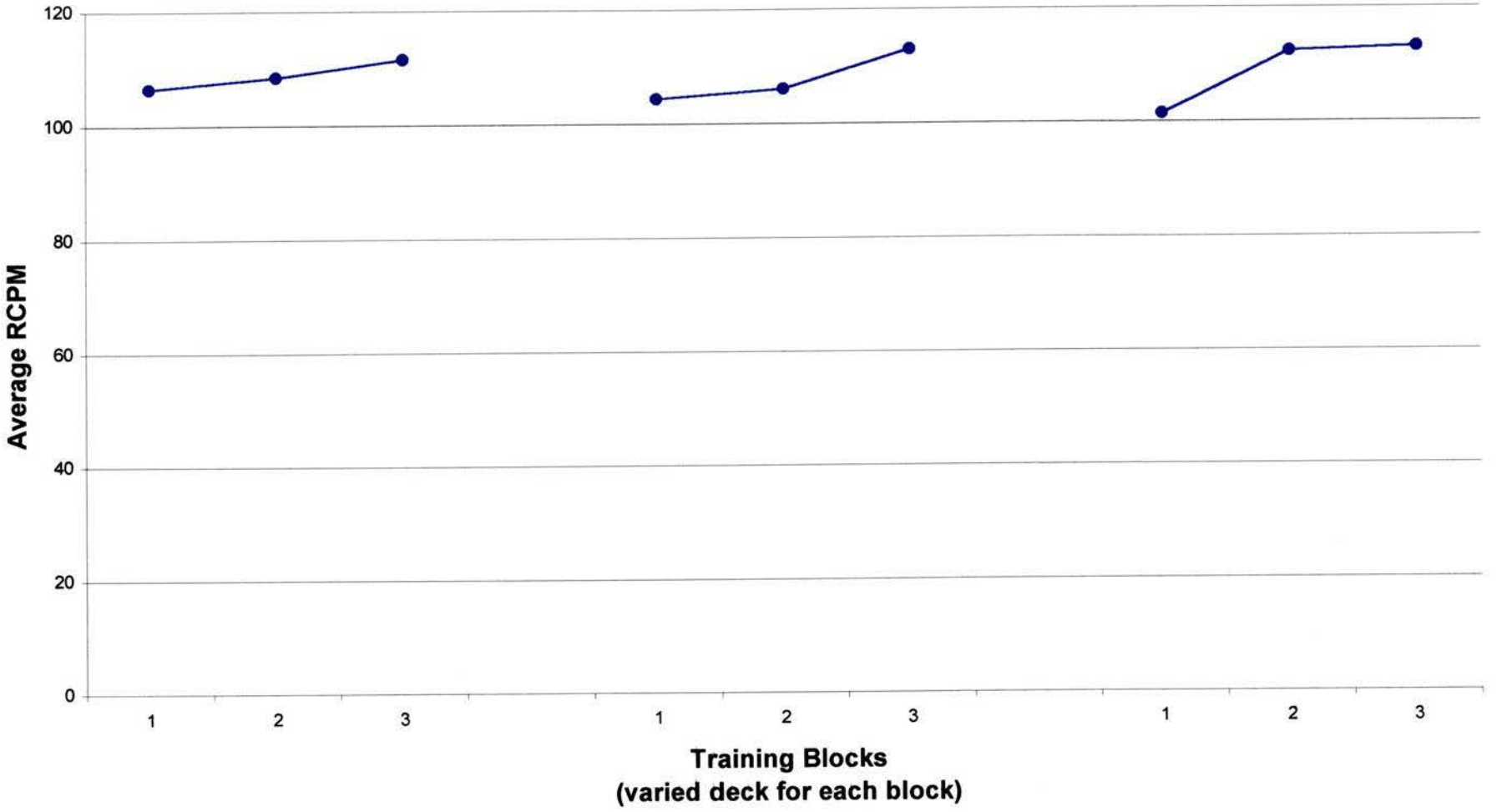


Figure 10 Training Session Rates for Letters
Participant 2: Variable Deck Condition
Each Point represents the rate correct per minute (RCPM) averaged over 15 trials for each block, 3 blocks per session.

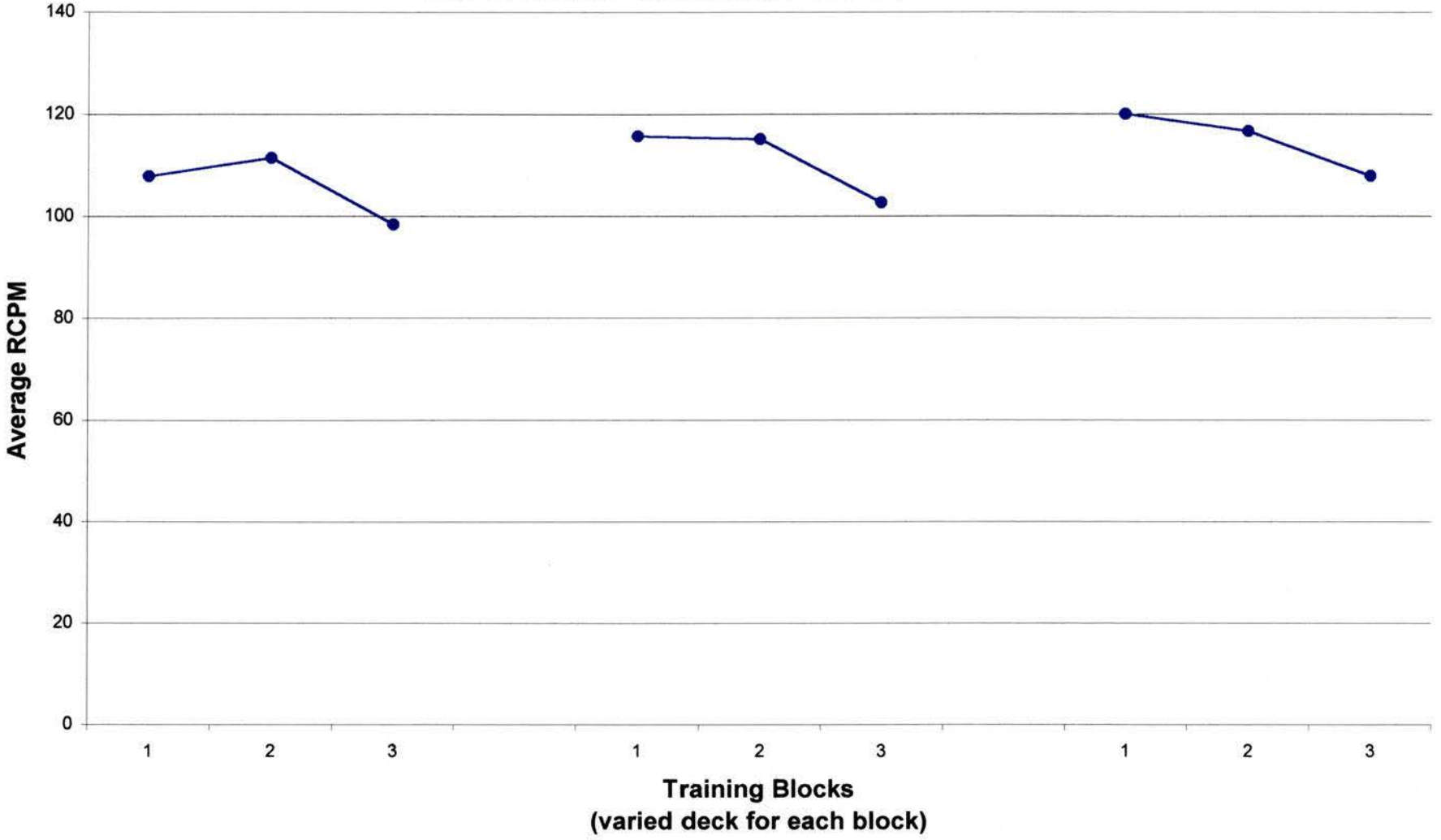


Figure 11 Training Session Rates for Letters
Participant 3: Variable Deck Condition
Each Point represents the rate correct per minute (RCPM) averaged over 15 trials for each block, 3 blocks per session.

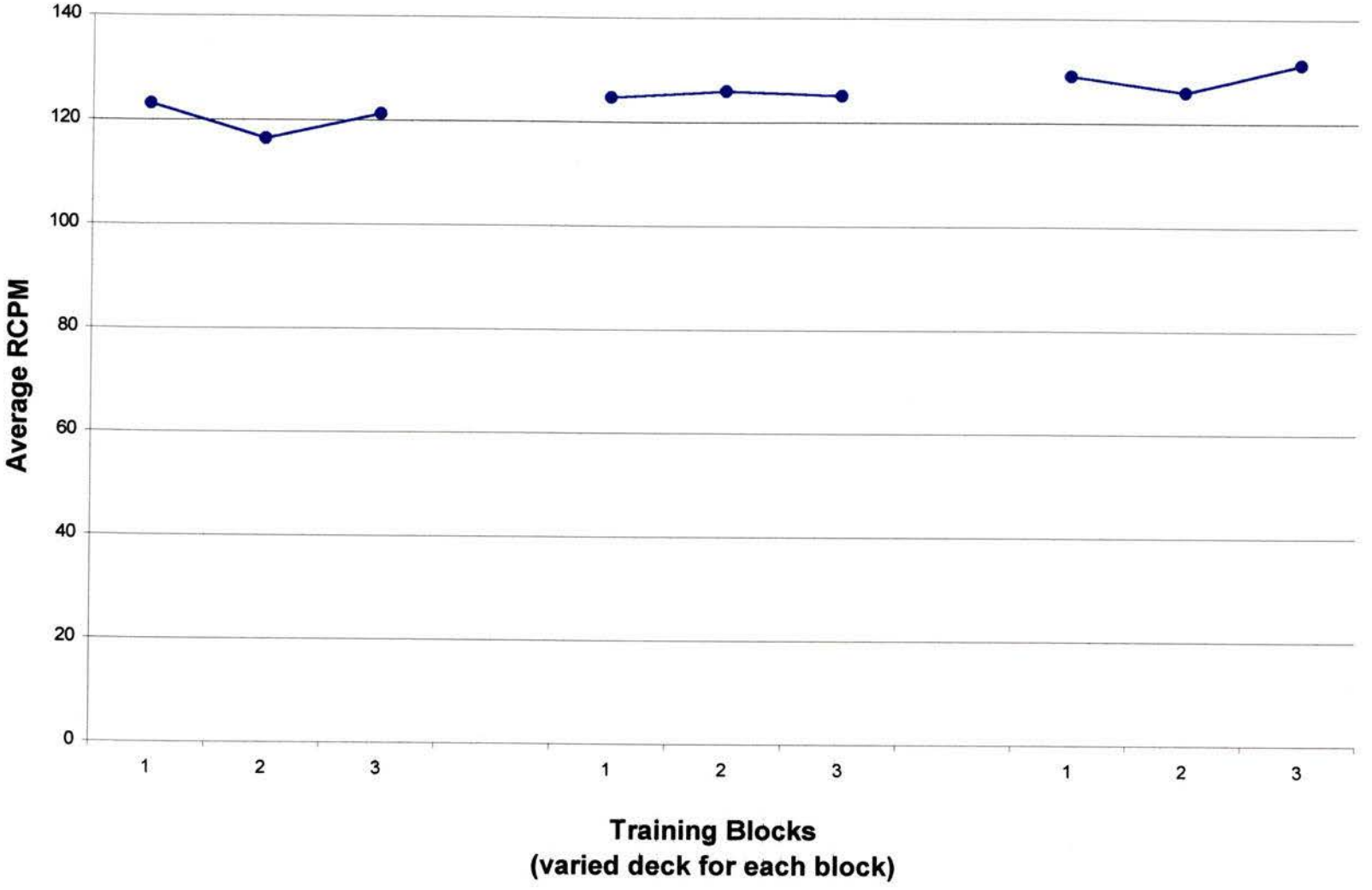


Figure 12 Training Session Rates for Letters
Participant 4: Variable Deck Condition
Each Point represents the RCPM averaged over
15 trials for each block, 3 blocks per session.

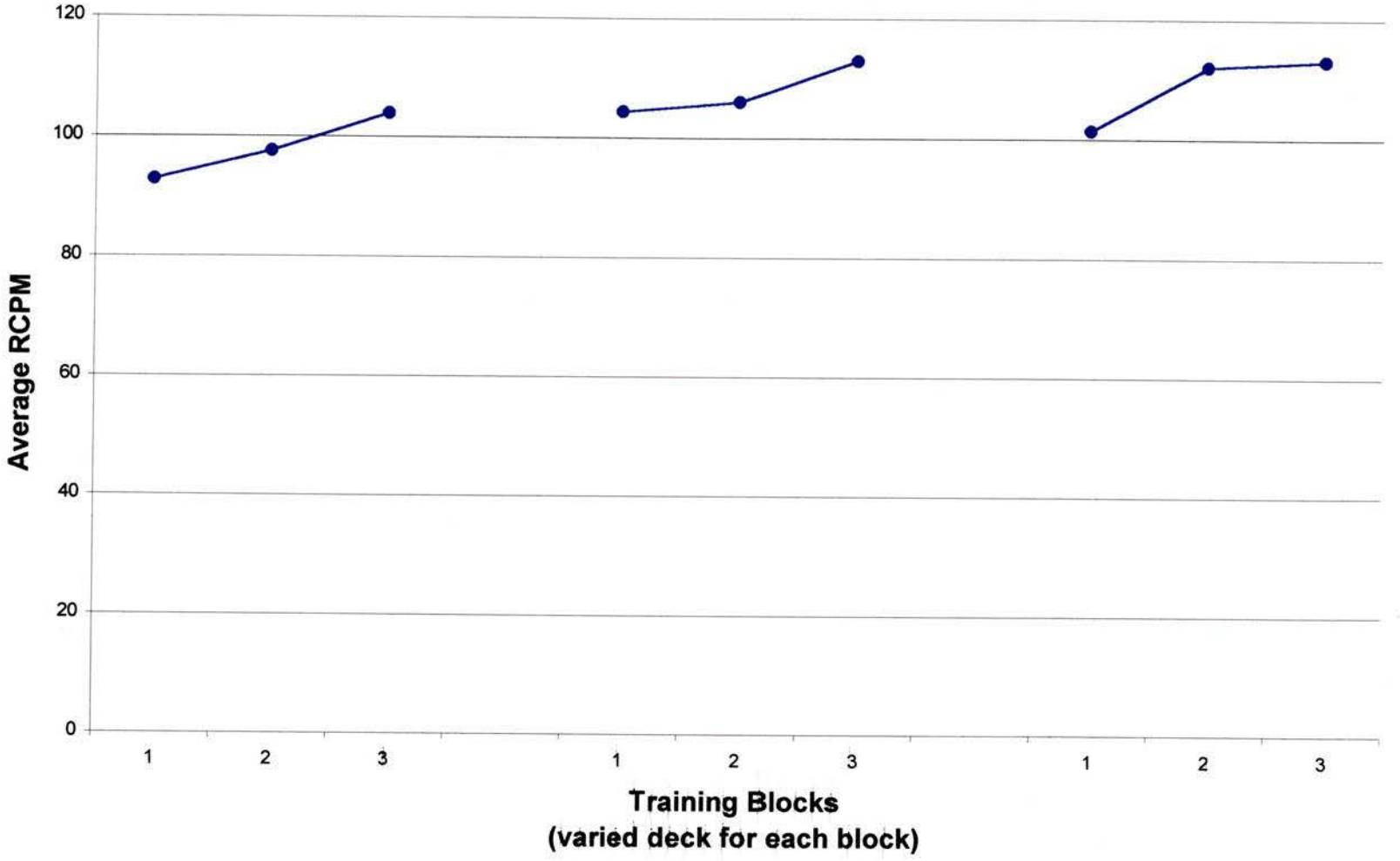


Figure 13 Training Session Rates for Synonyms vs. Antonyms
Participant 1: Variable Deck Condition
Each Point represents the RCPM averaged over
15 trials for each block, 3 blocks per session.

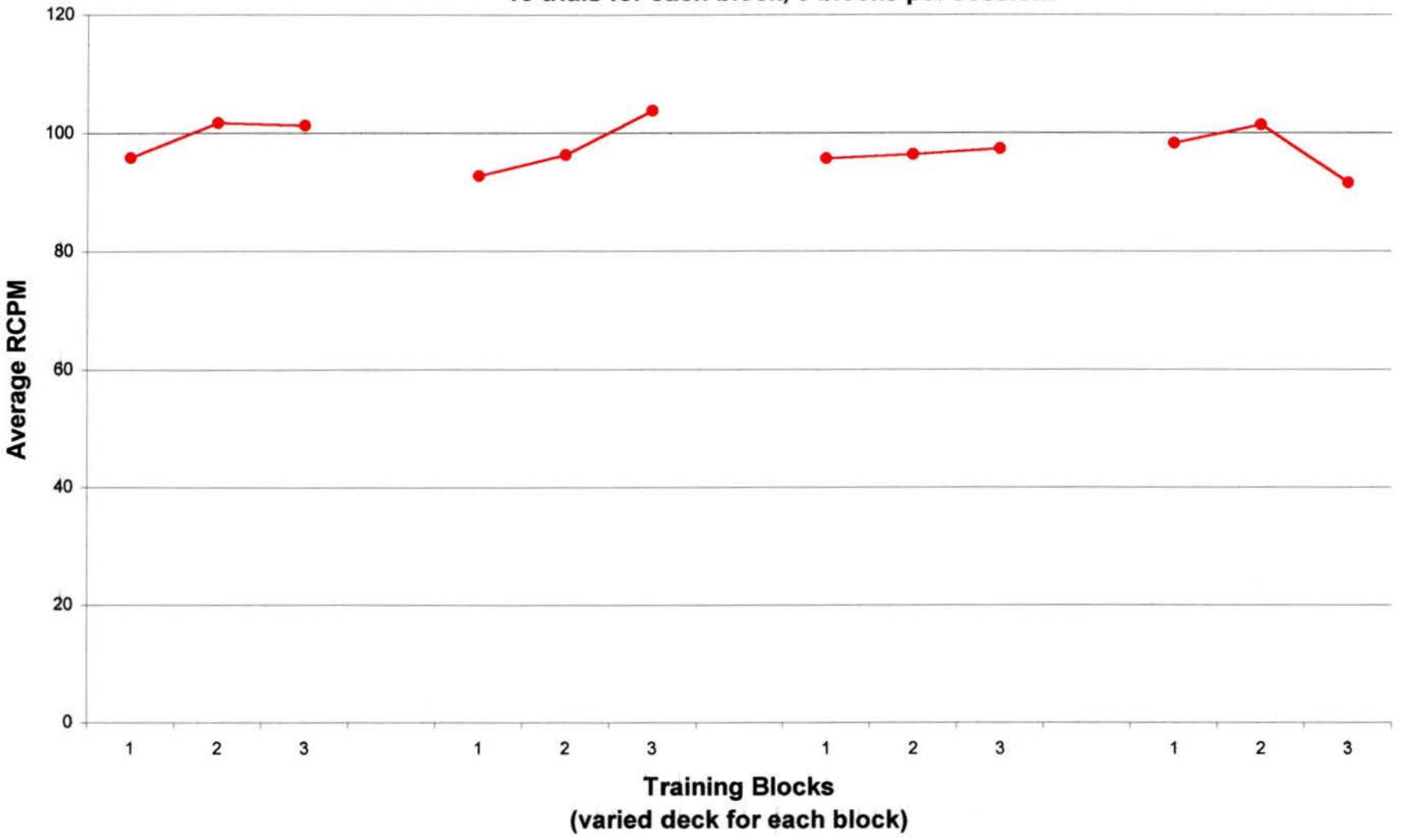


Figure 14 Training Session Rates for Synonyms vs. Antonyms
Participant 2: Variable Deck Condition
Each Point represents the rate correct per minute (RCPM) averaged over 15 trials for each block, 3 blocks per session.

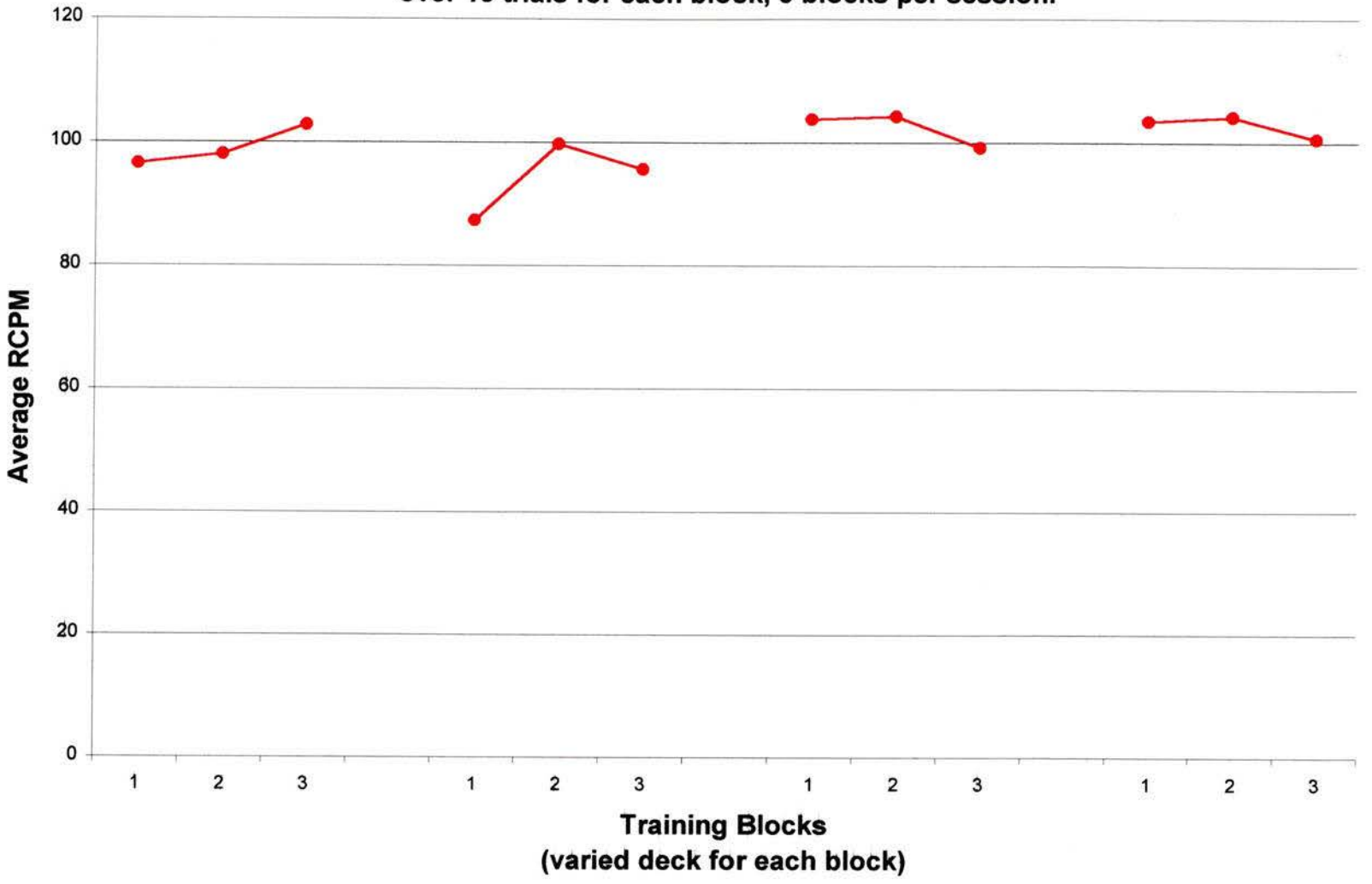


Figure 15 Training Session Rates for Synonyms vs. Antonyms
Participant 3: Variable Deck Condition
Each Point represents the rate correct per minute (RCPM) averaged over 15 trials for each block, 3 blocks per session.

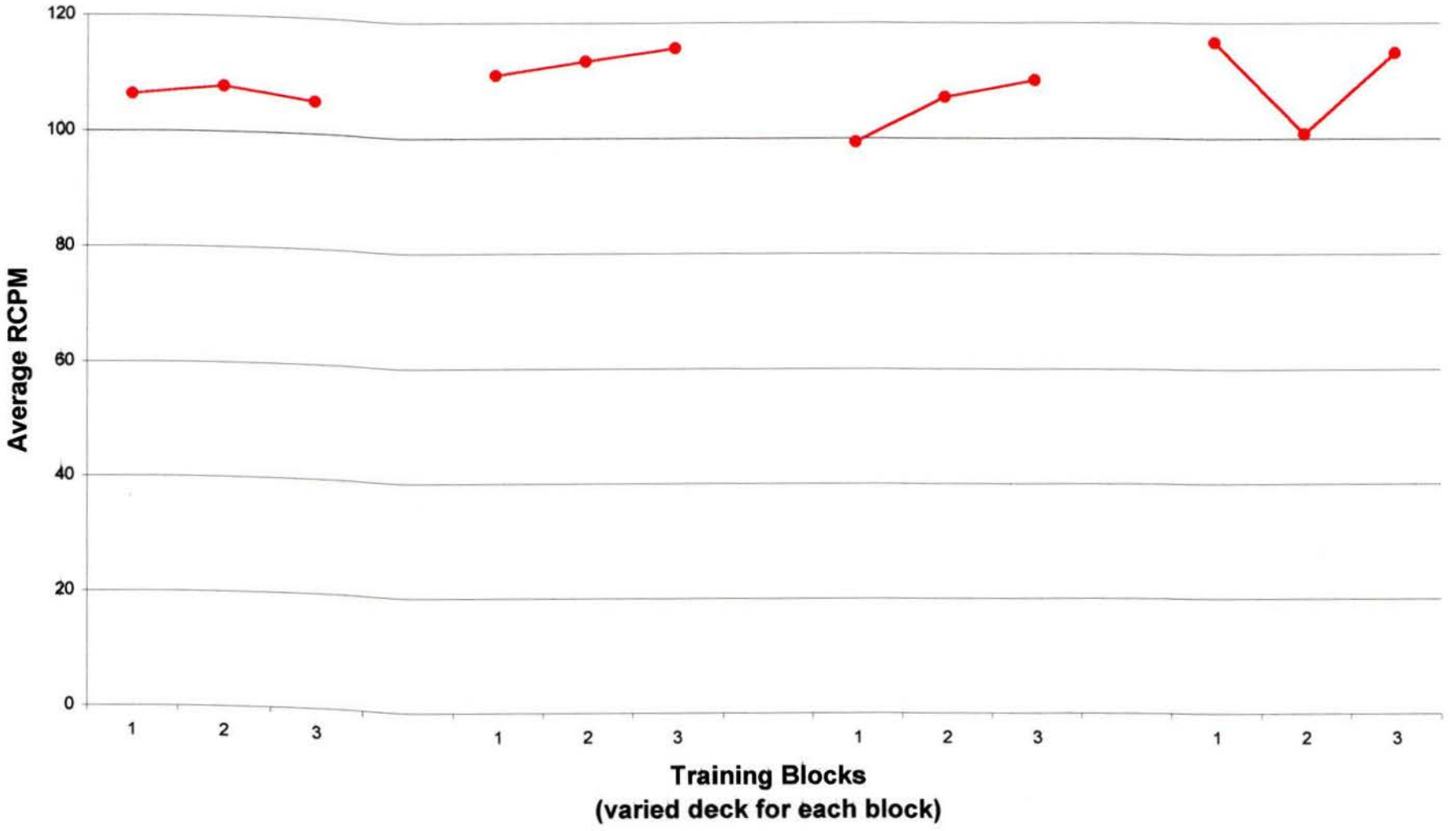


Figure 16 Training Session Rates for Synonyms vs. Antonyms
Participant 4: Variable Deck Condition
Each Point represents the RCPM averaged over
15 trials for each block, 3 blocks per session.

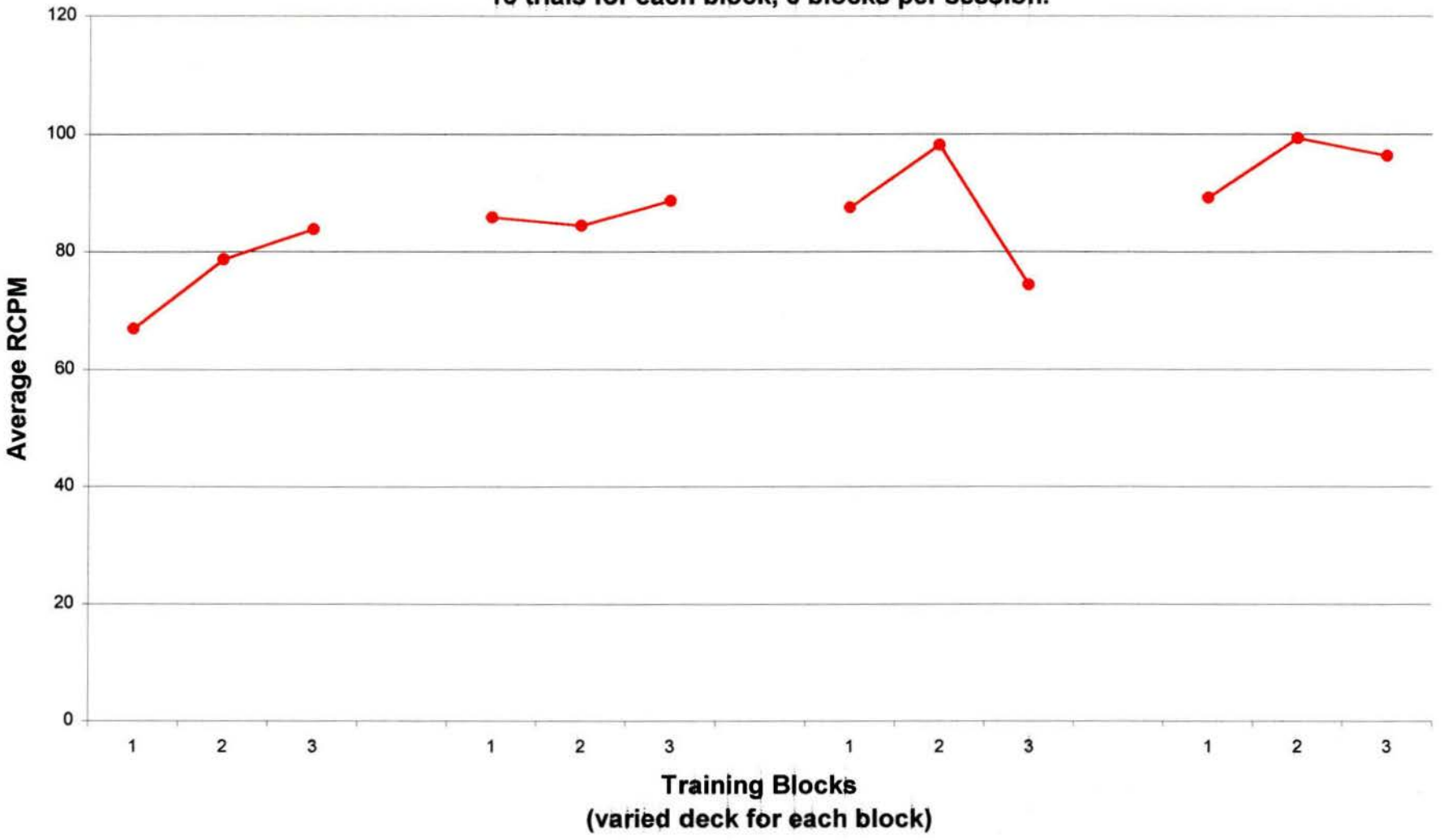


Figure 17 Training Session Rates for Sentences
Participant 1: Variable Deck Condition
Each Point represents the RCPM averaged over
15 trials for each block, 4 blocks per session.

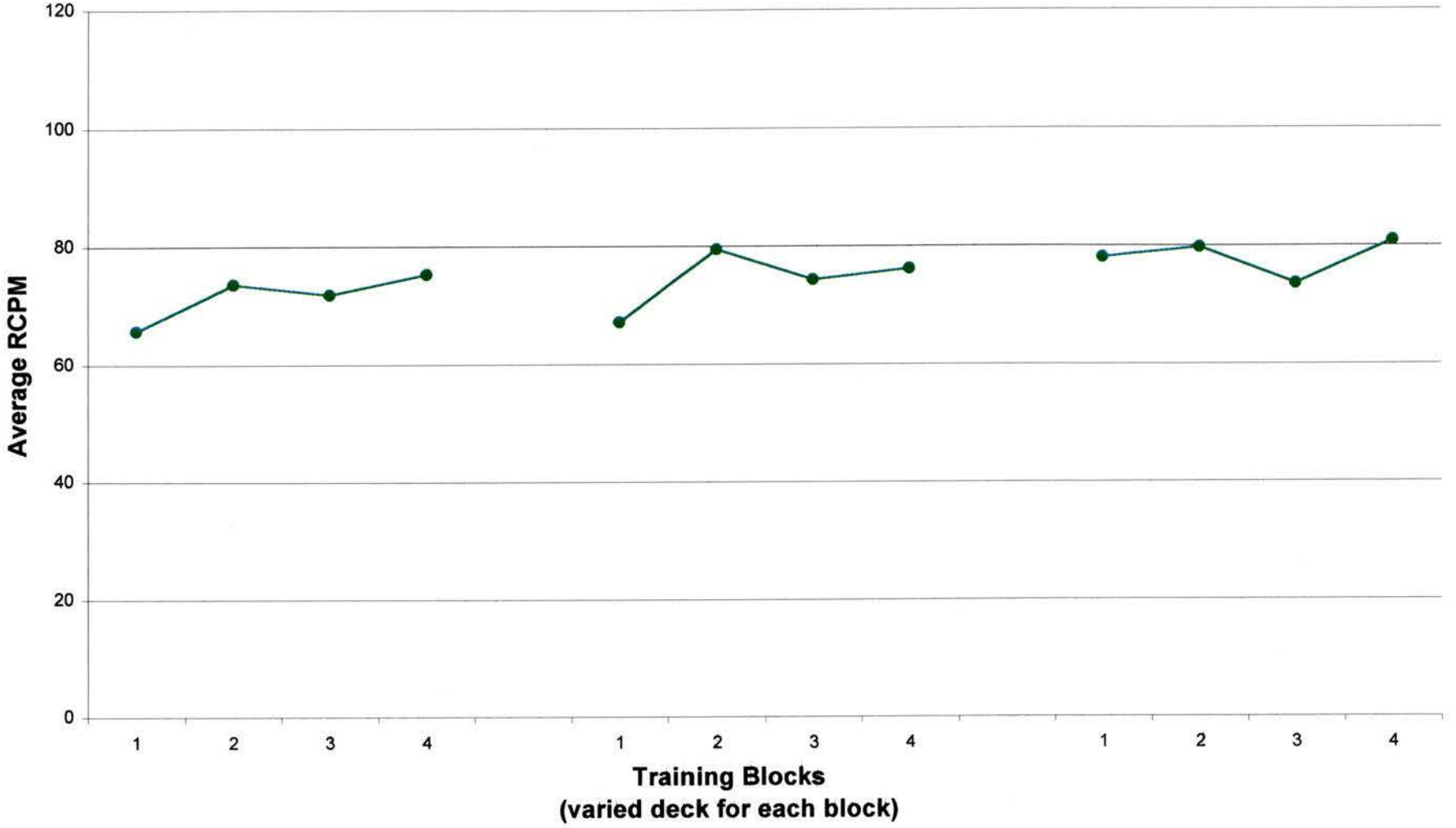


Figure 18 Training Session Rates for Sentences
Participant 2: Variable Deck Condition
Each Point represents the rate correct per minute (RCPM) averaged over 15 trials for each block, 4 blocks per session.

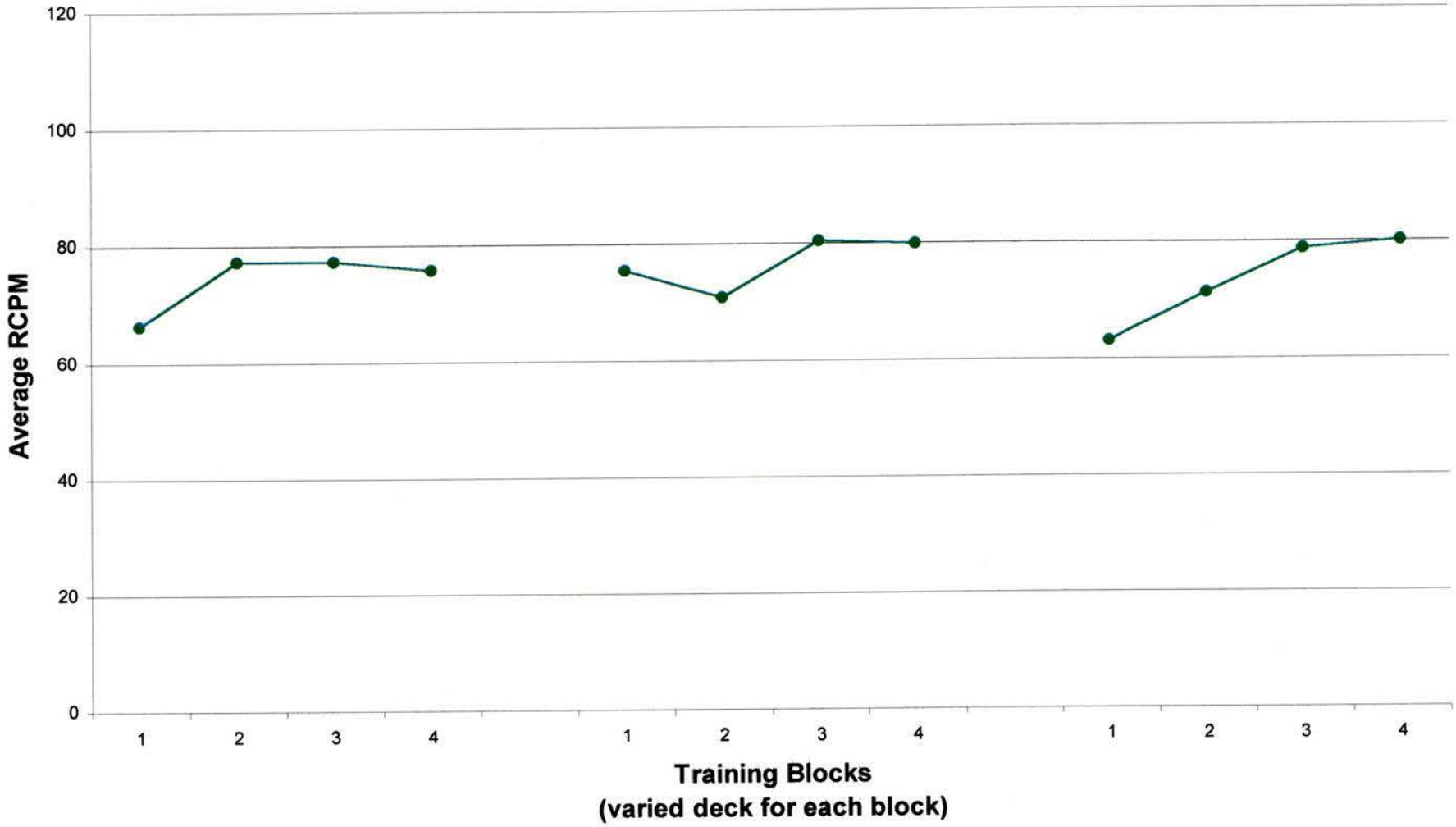


Figure 19 Training Session Rates for Sentences
Participant 3: Variable Deck Condition
Each Point represents the rate correct per minute (RCPM) averaged over 15 trials for each block, 4 blocks per session.

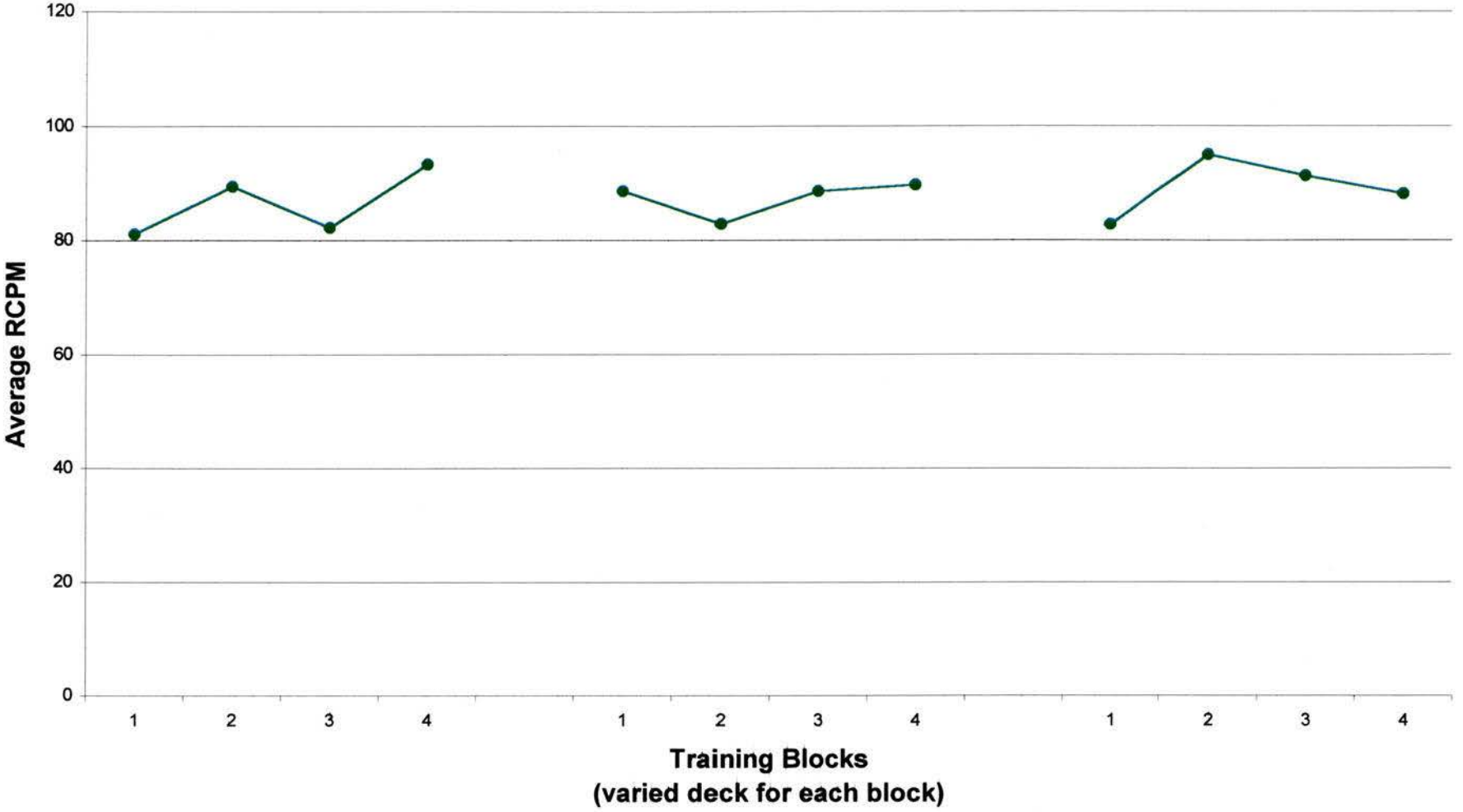
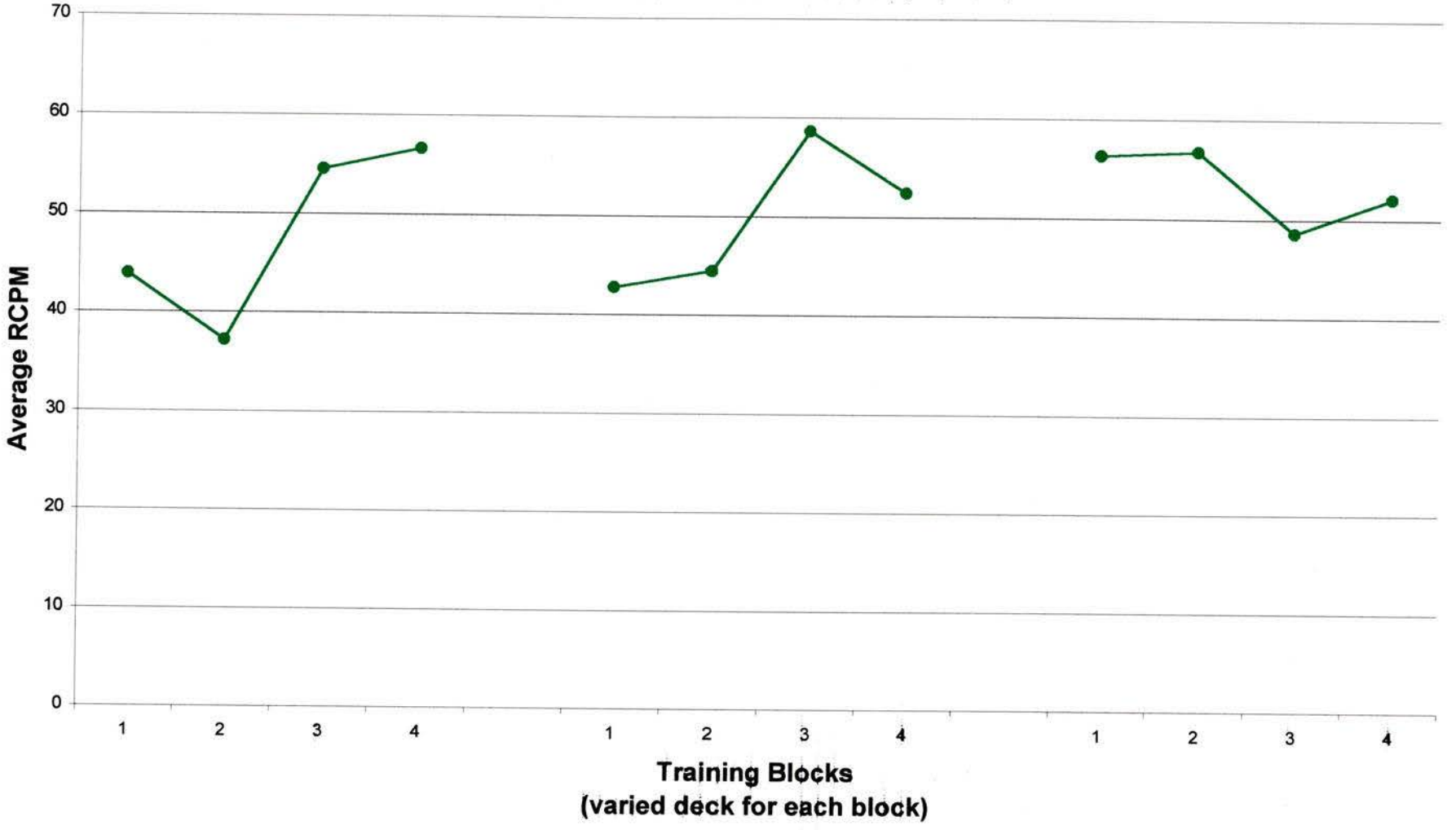


Figure 20 Training Session Rates for Sentences
Participant 4: Variable Deck Condition
Each Point represents the RCPM averaged over
15 trials for each block, 3 blocks per session.



Appendix E

The following series of graphs (1 per participant) illustrate the average Training Day Rates for the Original Homonyms, Familiar Homonyms, Letters, Synonyms, and Sentences for each participant. Each plotted point represents the rate correct per minute (RCPM) averaged over the 3 blocks in a training session for each task.

Figure 21 Average Training Day Rates over Tasks
Participant 1: Same/Variable Deck Condition
Each point represents the RCPM averaged over the 3 blocks in a training session, for each task.

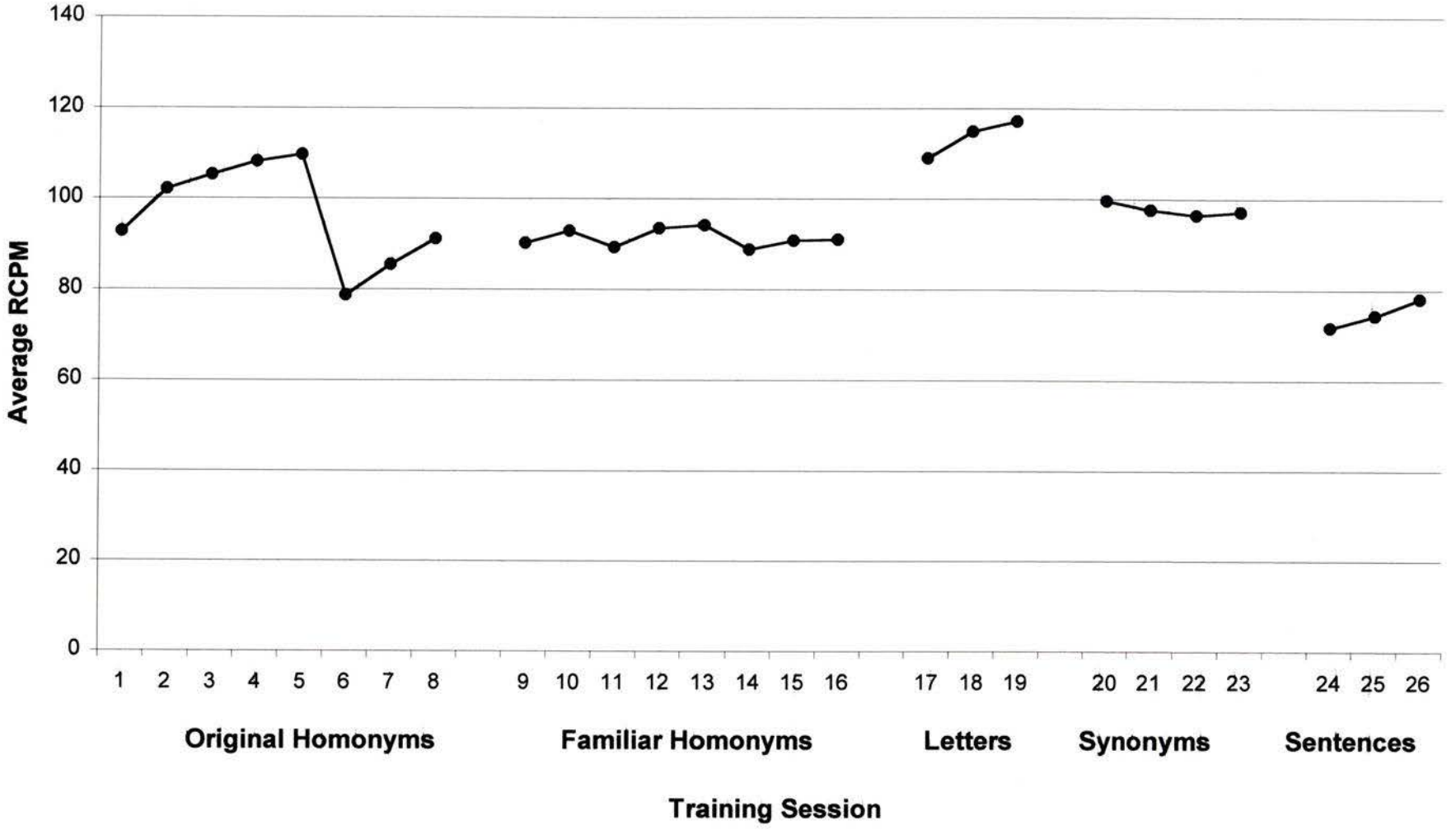


Figure 22 Average Training Day Rates over Tasks
Participant 2: Variable Deck Condition
Each point represents the RCPM averaged over the 3 blocks in a training session, for each task.

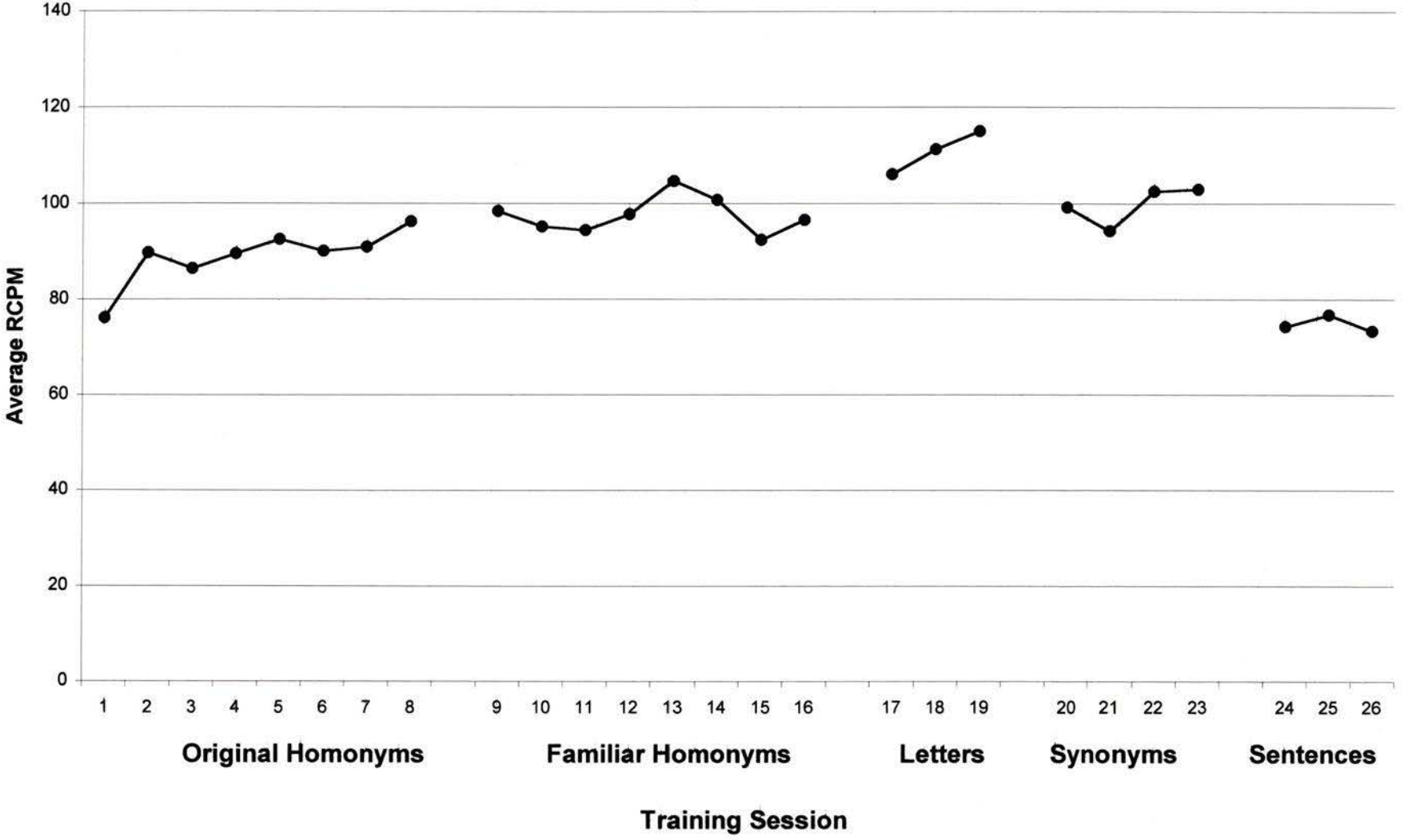


Figure 23 Average Training Day Rates over Tasks
Participant 3: Variable Deck Condition
Each point represents the RCPM averaged over the 3 blocks in a training session, for each task.

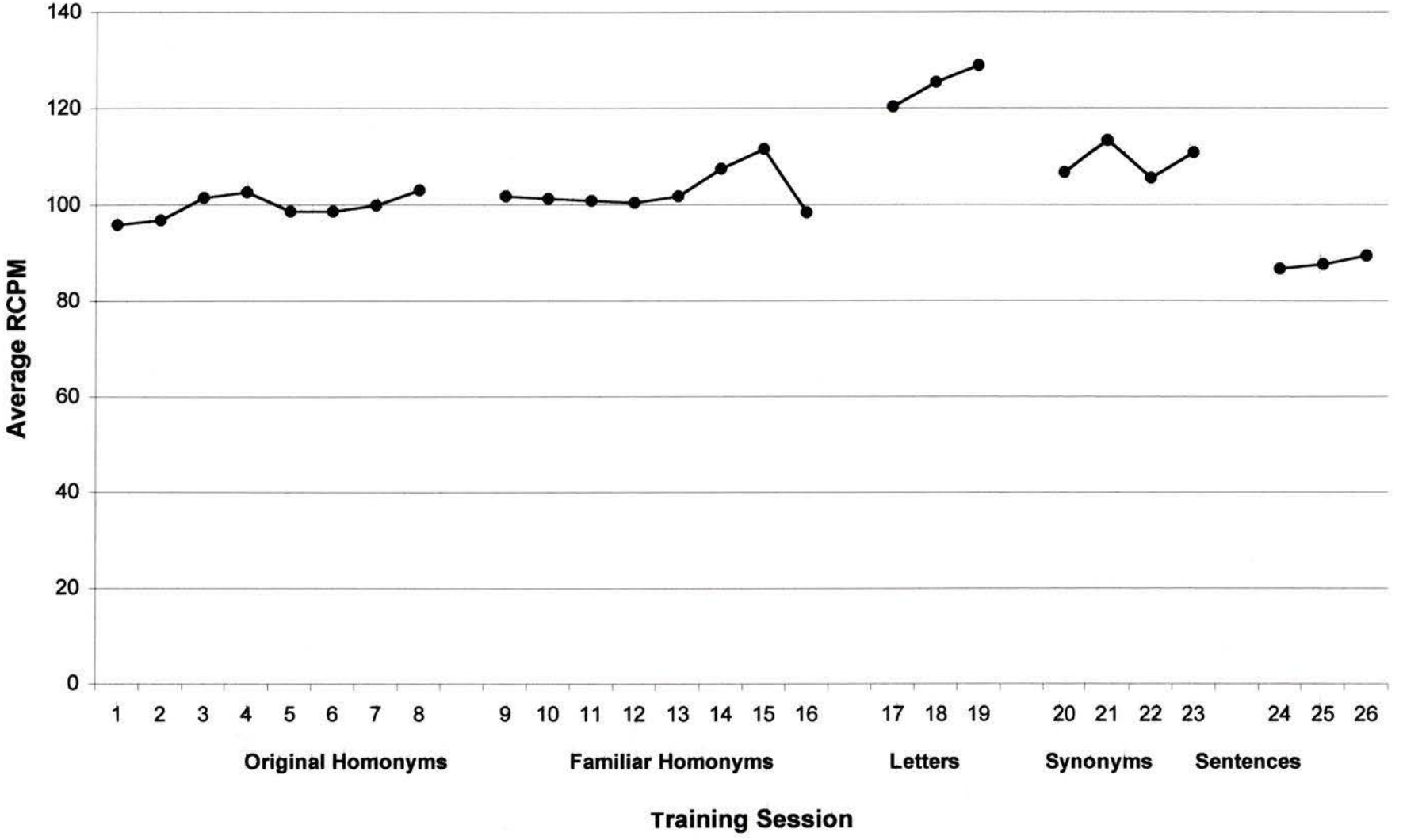
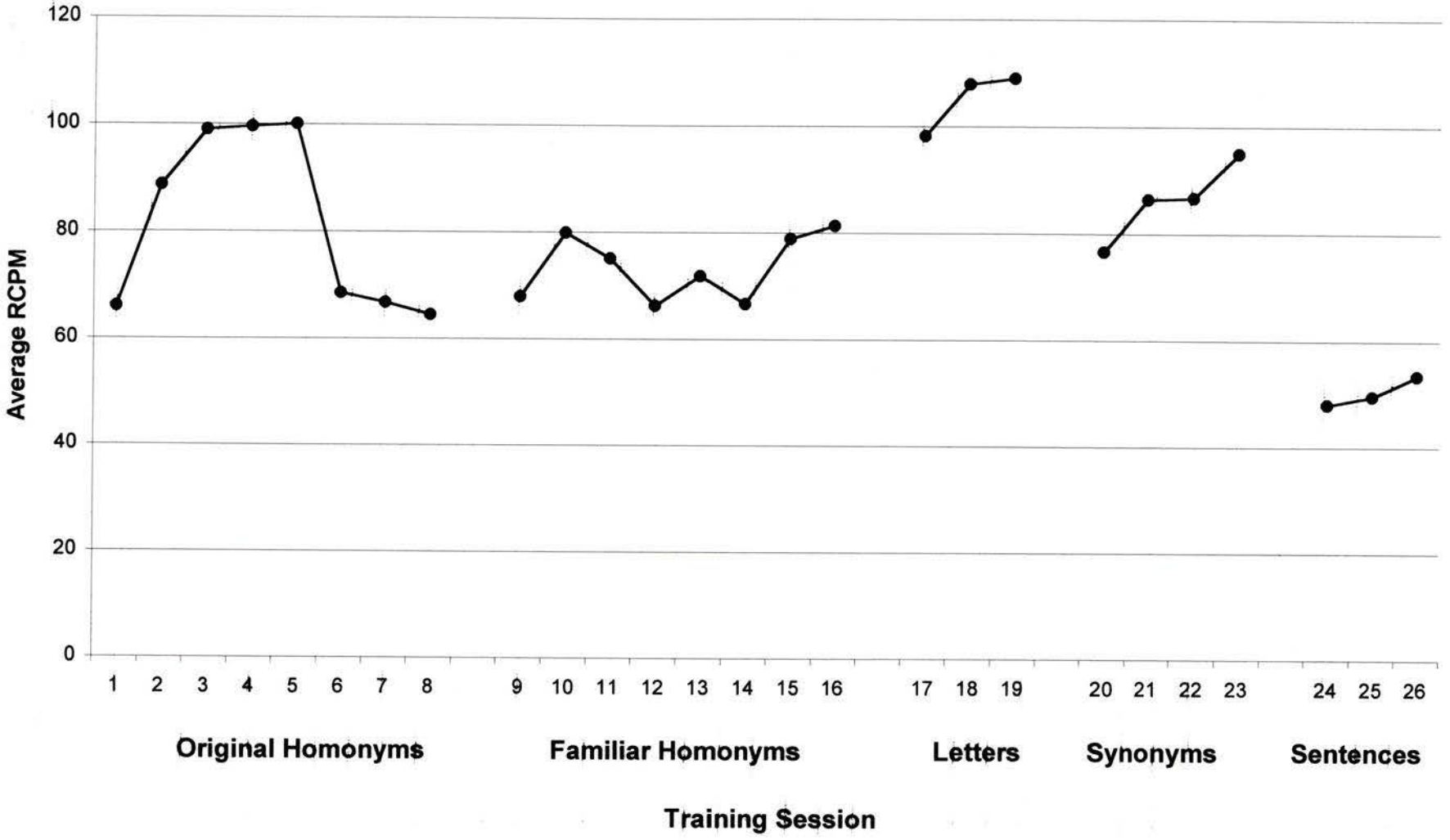


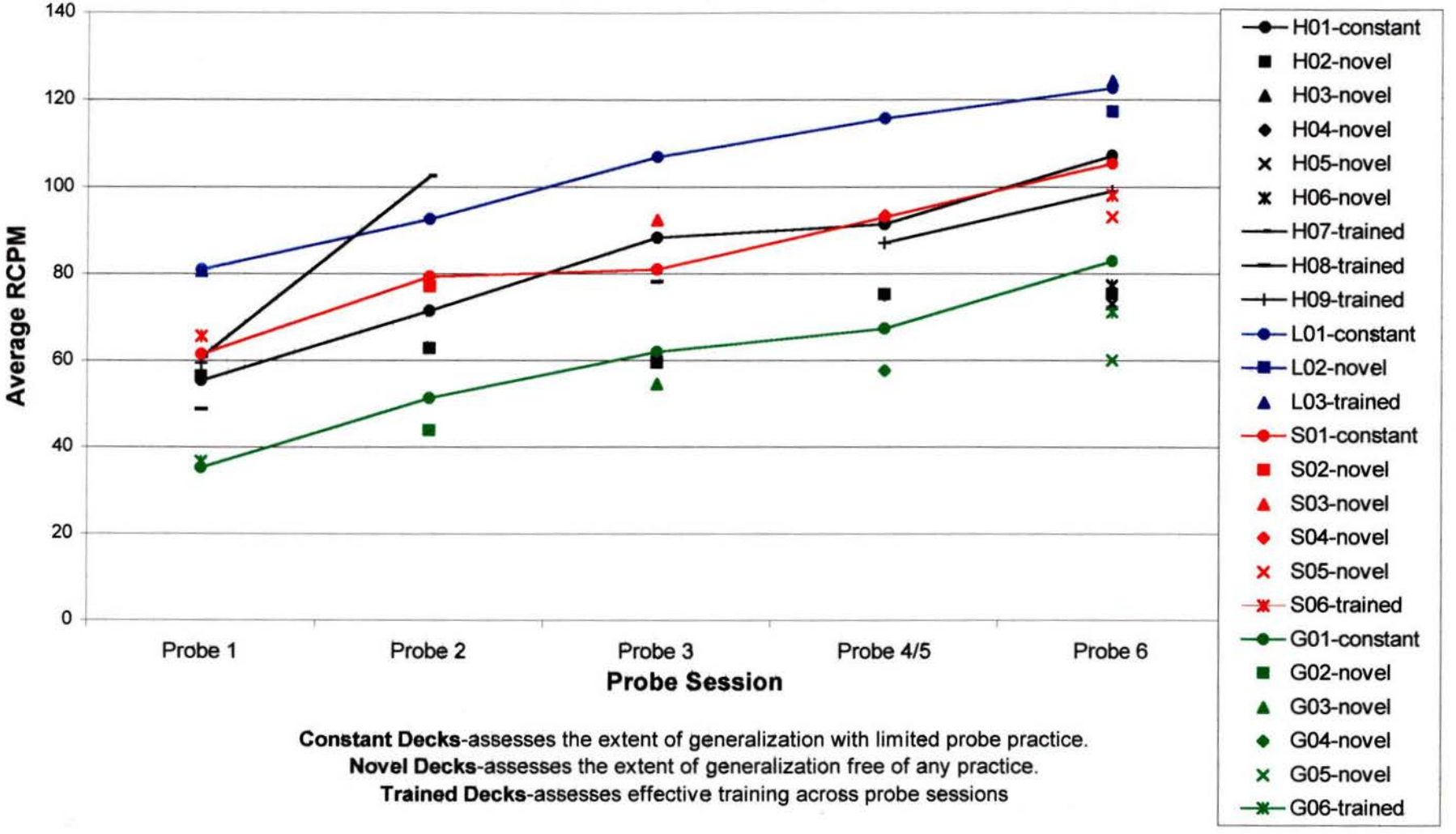
Figure 24 Average Training Day Rates over Tasks
Participant 4: Same/Variable Deck Condition
Each point represents the RCPM averaged over the 3 blocks in a training session, for each task.



Appendix F

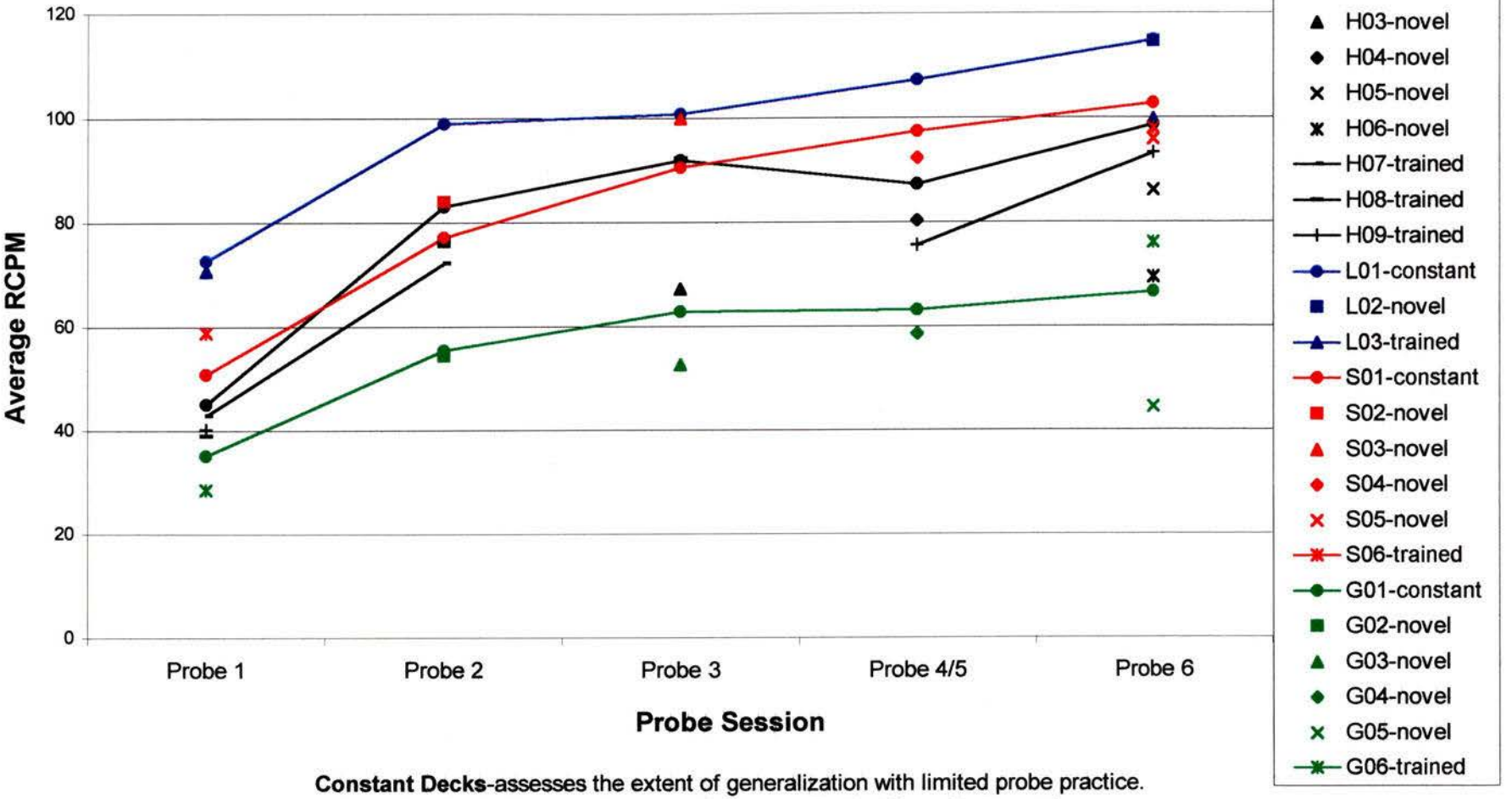
The following series of graphs (1 per participant) illustrate the Probe Session Rates for the Homonyms, Letters, Synonyms, and Sentences for each participant over six probe sessions. Each plotted point represents the rate correct per minute (RCPM) averaged over 5 trials for each task block, with 1 block per deck per session

Figure 25 Probe Session Rates for Six Probe Sessions
Participant 1: Same/Variable Deck Condition
Each point represents the RCPM averaged over
5 trials for each task block, 1 block per deck per session.



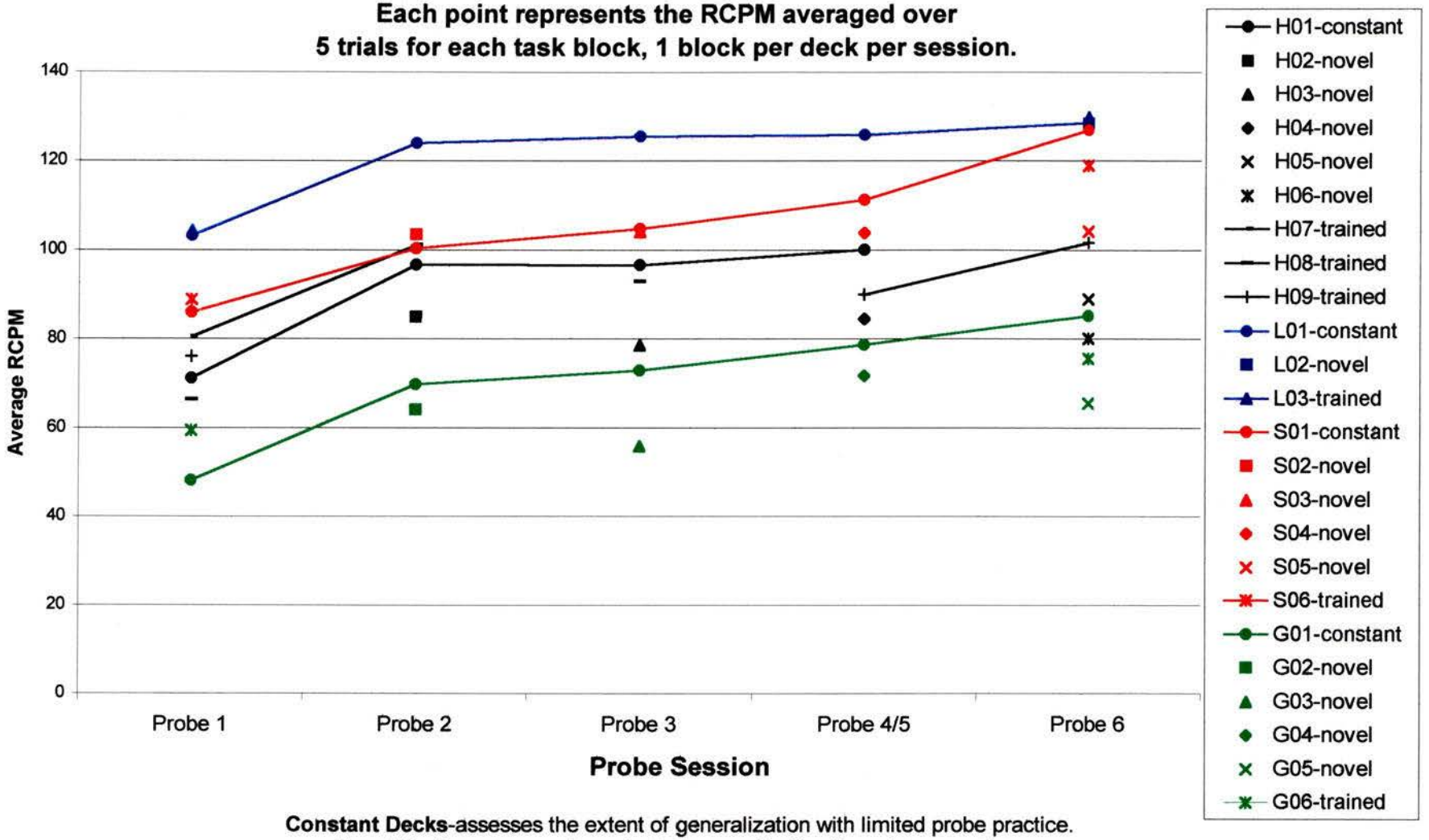
Constant Decks-assesses the extent of generalization with limited probe practice.
Novel Decks-assesses the extent of generalization free of any practice.
Trained Decks-assesses effective training across probe sessions

Figure 26 Probe Session Rates for Six Probe Sessions
Participant 2: Same/Variable Deck Condition
Each point represents the RCPM averaged over
5 trials for each task block, 1 block per deck per session.



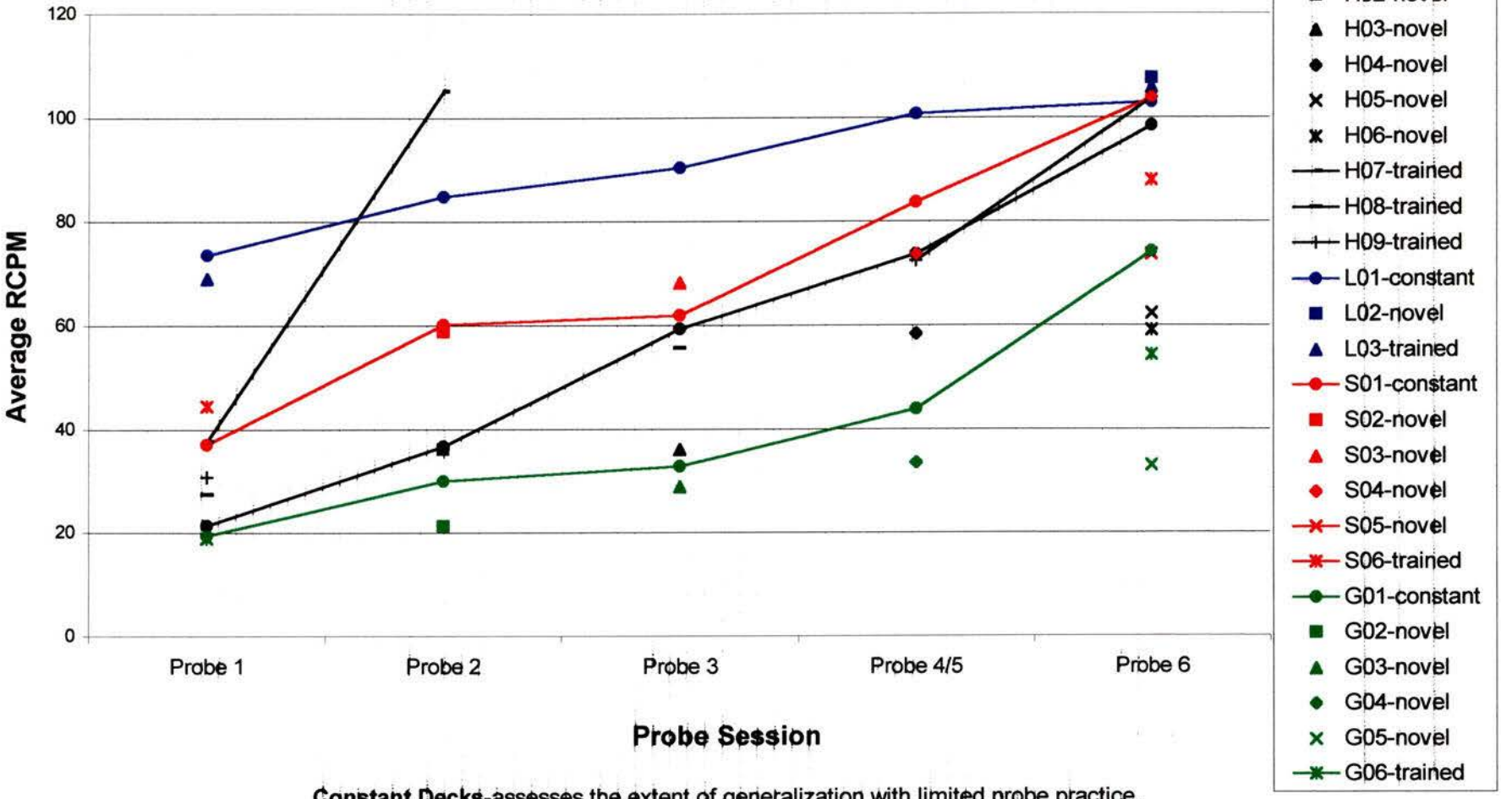
Constant Decks-assesses the extent of generalization with limited probe practice.
Novel Decks-assesses the extent of generalization free of any practice.
Trained Decks-assesses effective training across probe sessions

Figure 27 Probe Session Rates for Six Probe Sessions
Participant 3: Variable Deck Condition
Each point represents the RCPM averaged over
5 trials for each task block, 1 block per deck per session.



Constant Decks-assesses the extent of generalization with limited probe practice.
Novel Decks-assesses the extent of generalization free of any practice.
Trained Decks-assesses effective training across probe sessions

Figure 28 Probe Session Rates for Six Probe Sessions
Participant 4: Same/Variable Deck Condition
Each point represents the RCPM averaged over
5 trials for each task block, 1 block per deck per session.



Constant Decks-assesses the extent of generalization with limited probe practice.
Novel Decks-assesses the extent of generalization free of any practice.
Trained Decks-assesses effective training across probe sessions

Appendix G

The following series of graphs (4 per participant) illustrate the Probe Session Averages for the Homonyms, Letters, Synonyms, and Sentences for each participant. Each plotted point represents the rate correct per minute (RCPM) for the constant, novel, and trained deck for each task in each probe session.

Figure 29 Probe Session Averages for the Homonym Decks
Participant 1: Same/Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained homonym deck in each probe session

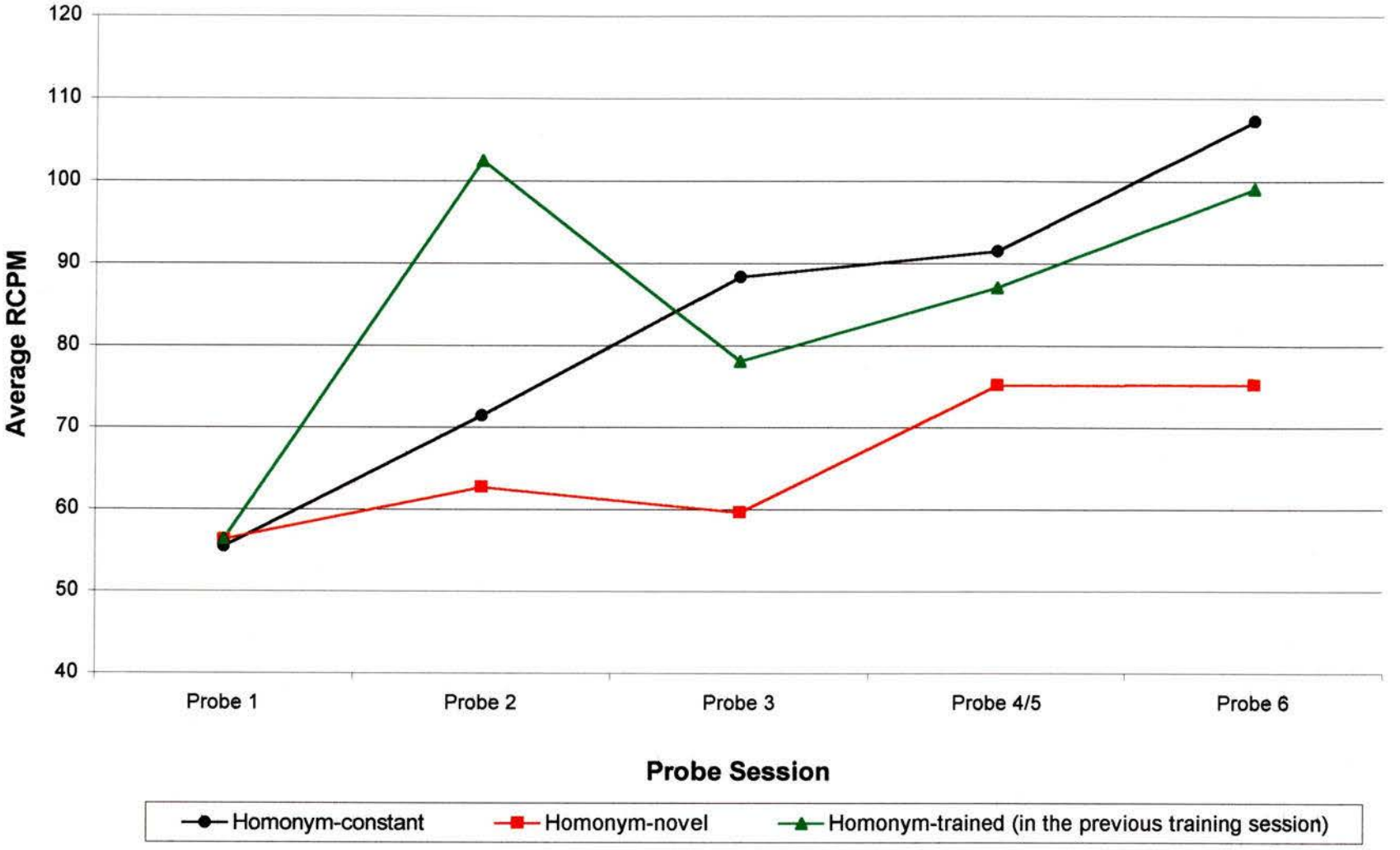


Figure 30 Probe Session Averages for the Homonym Decks
Participant 2: Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained homonym deck in each probe session

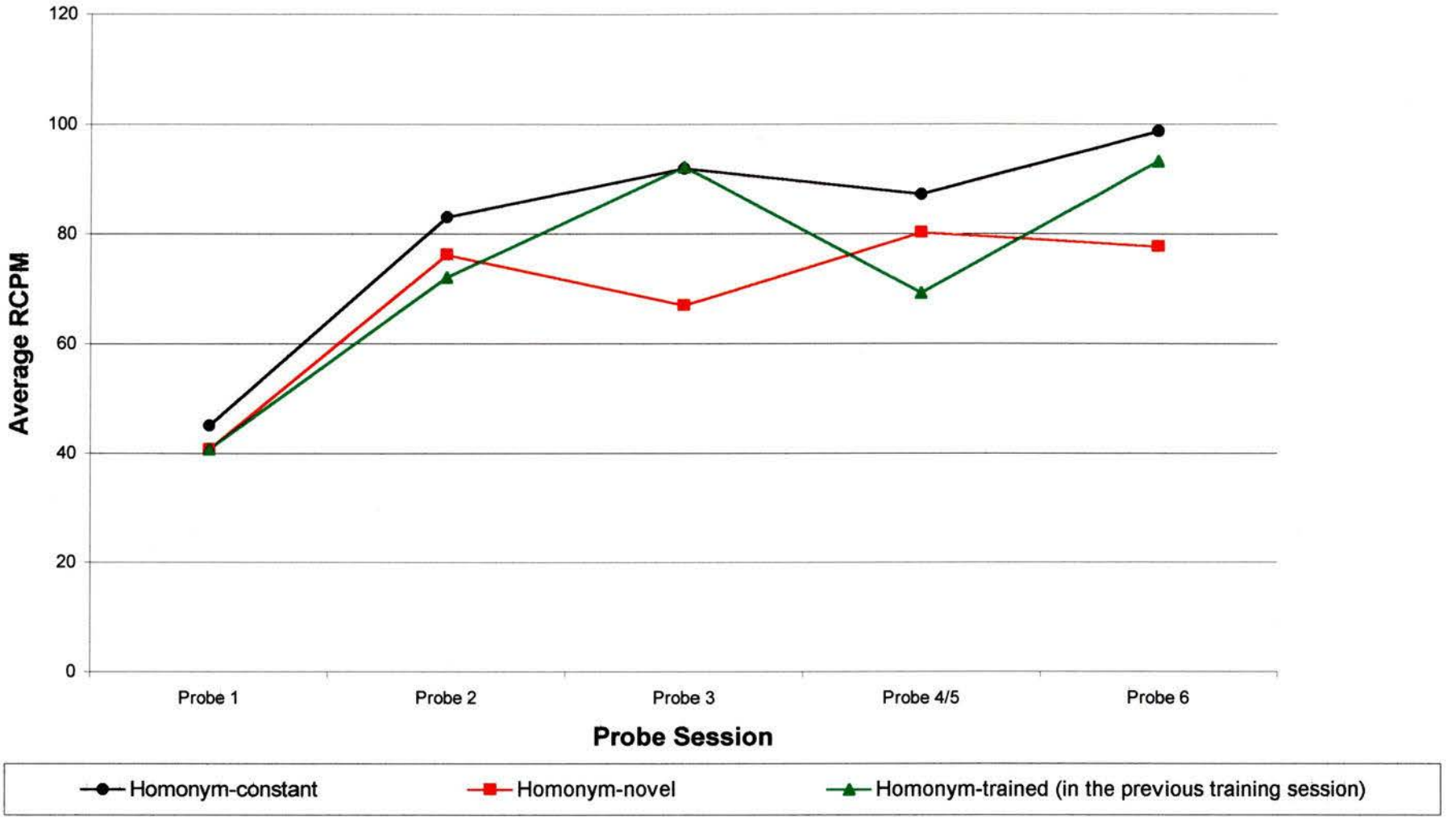


Figure 31 Probe Session Averages for the Homonym Decks
Participant 3: Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained homonym deck in each probe session

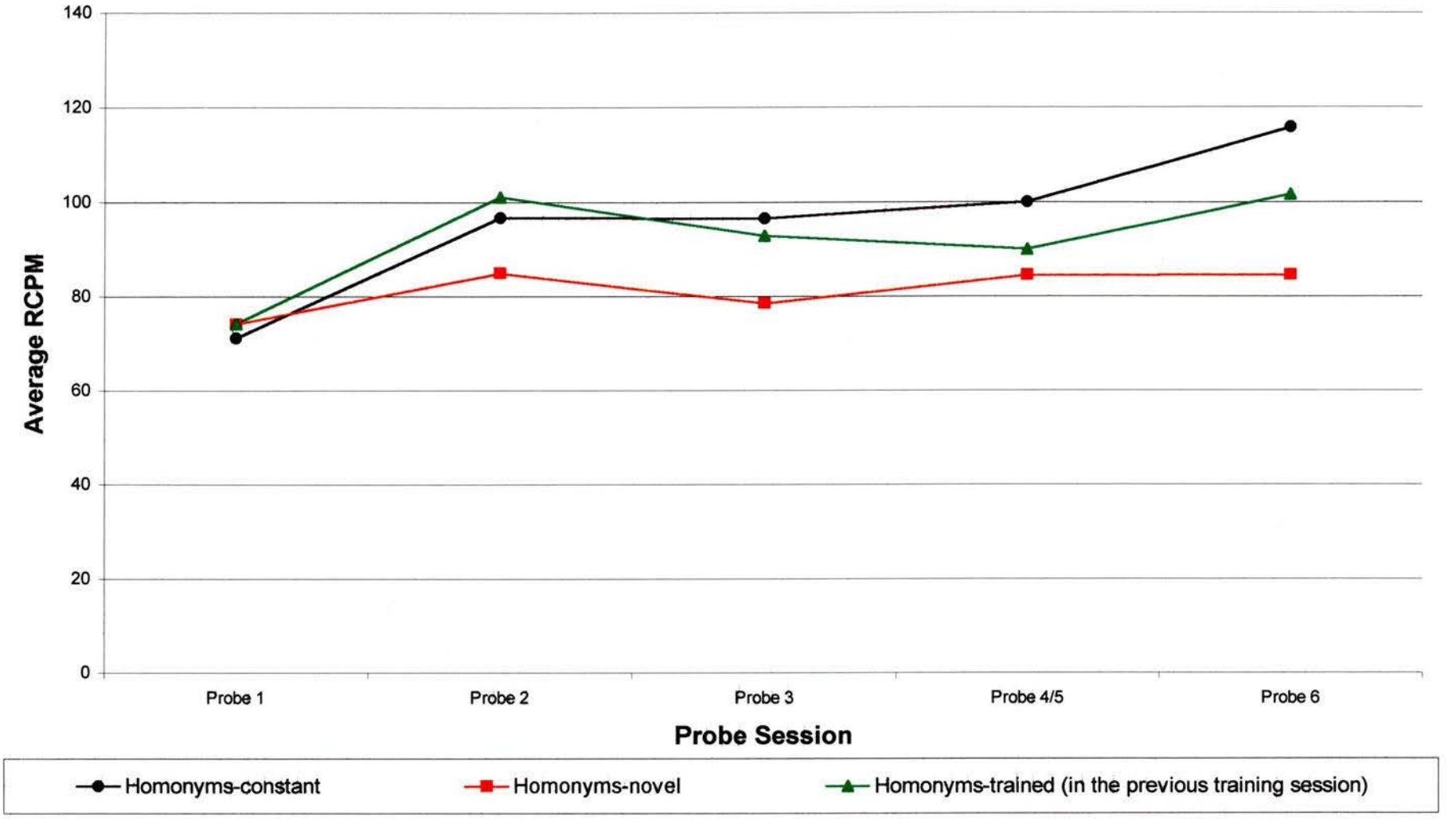


Figure 32 Probe Session Averages for the Homonym Decks
Participant 4: Same/Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained homonym deck in each probe session

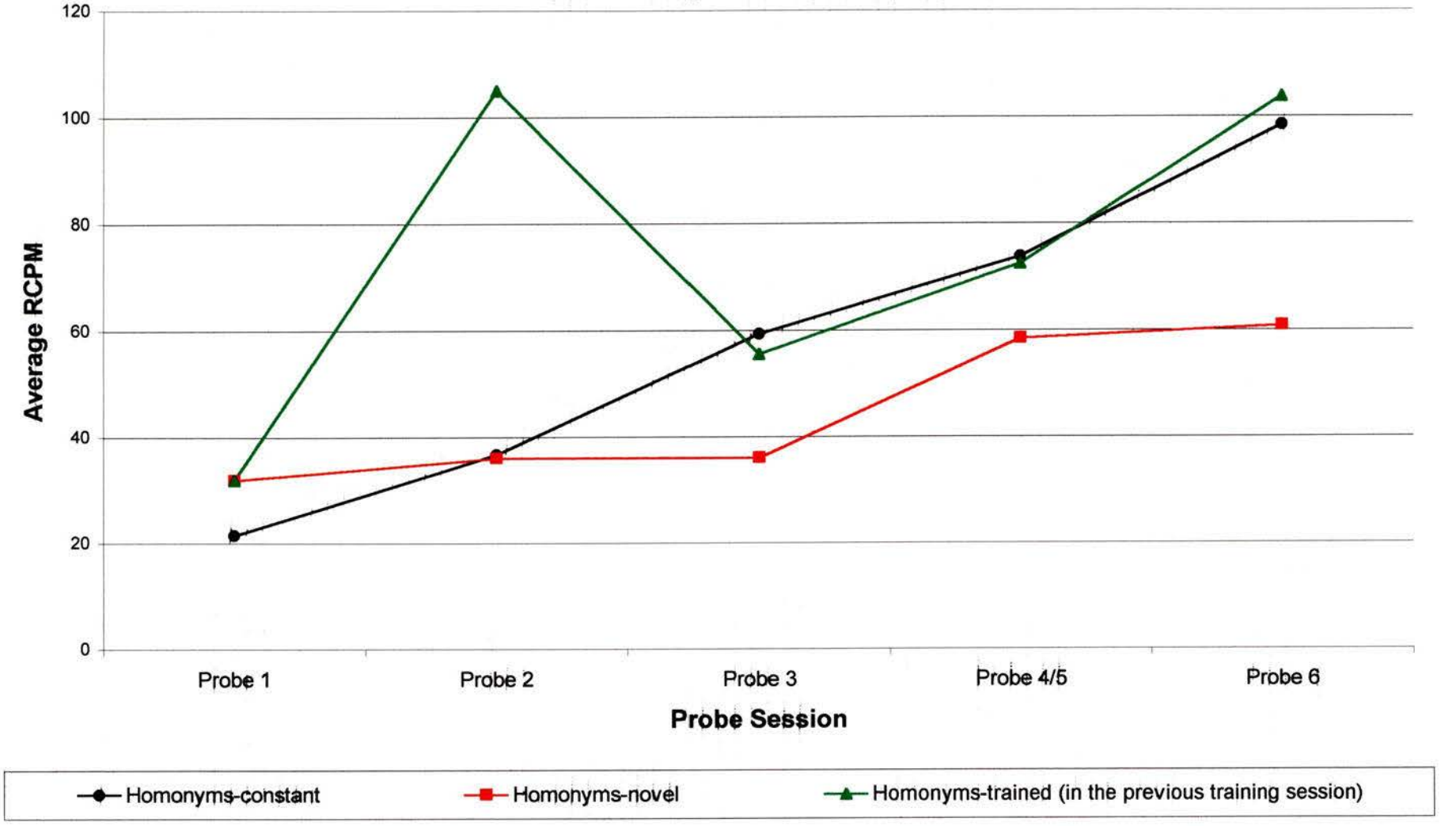


Figure 33 Probe Session Averages for the Letter Decks
Participant 1: Same/Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained letter deck in each probe session

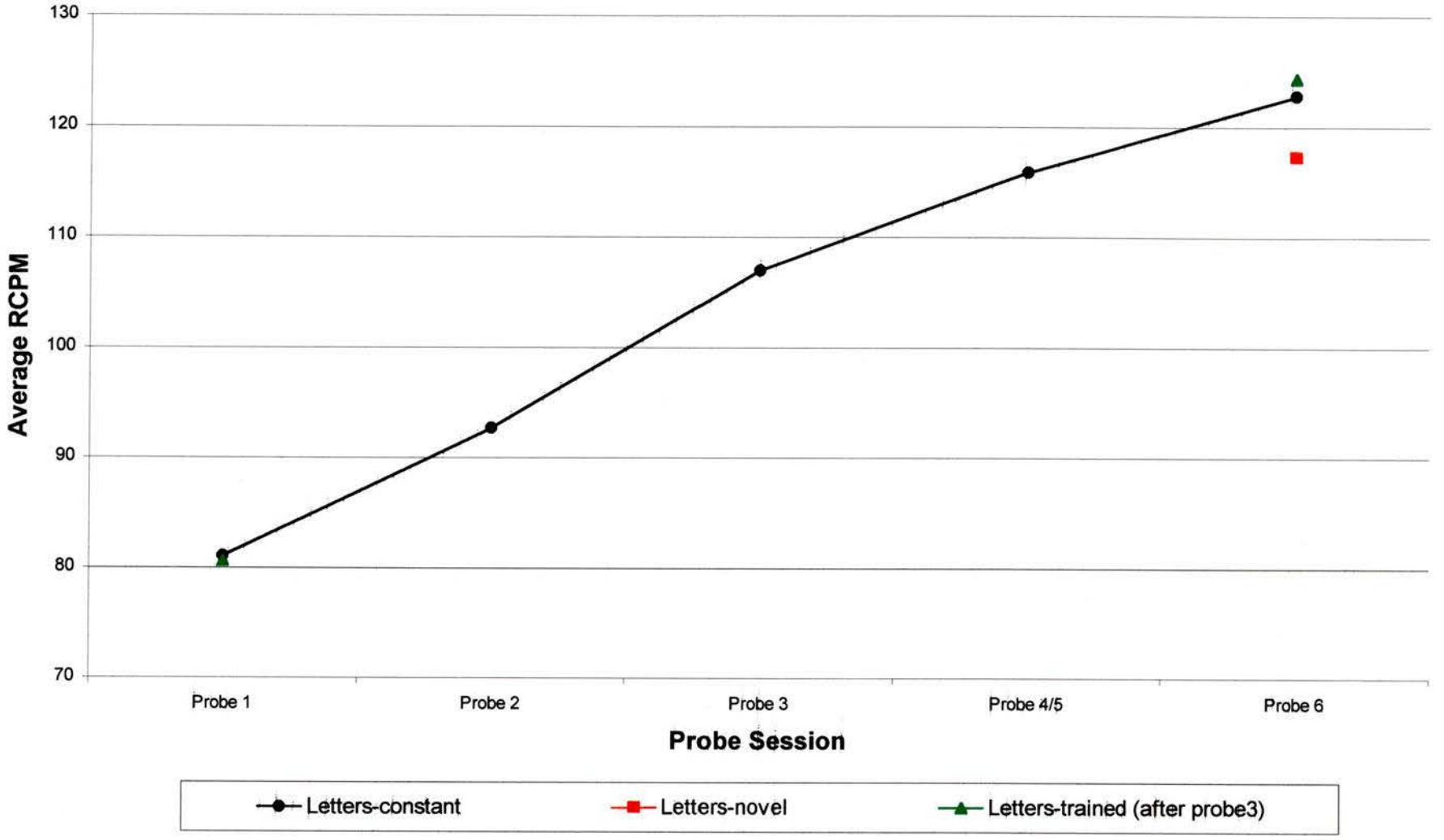


Figure 34 Probe Session Averages for the Letter Decks
Participant 2: Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained letter deck in each probe session

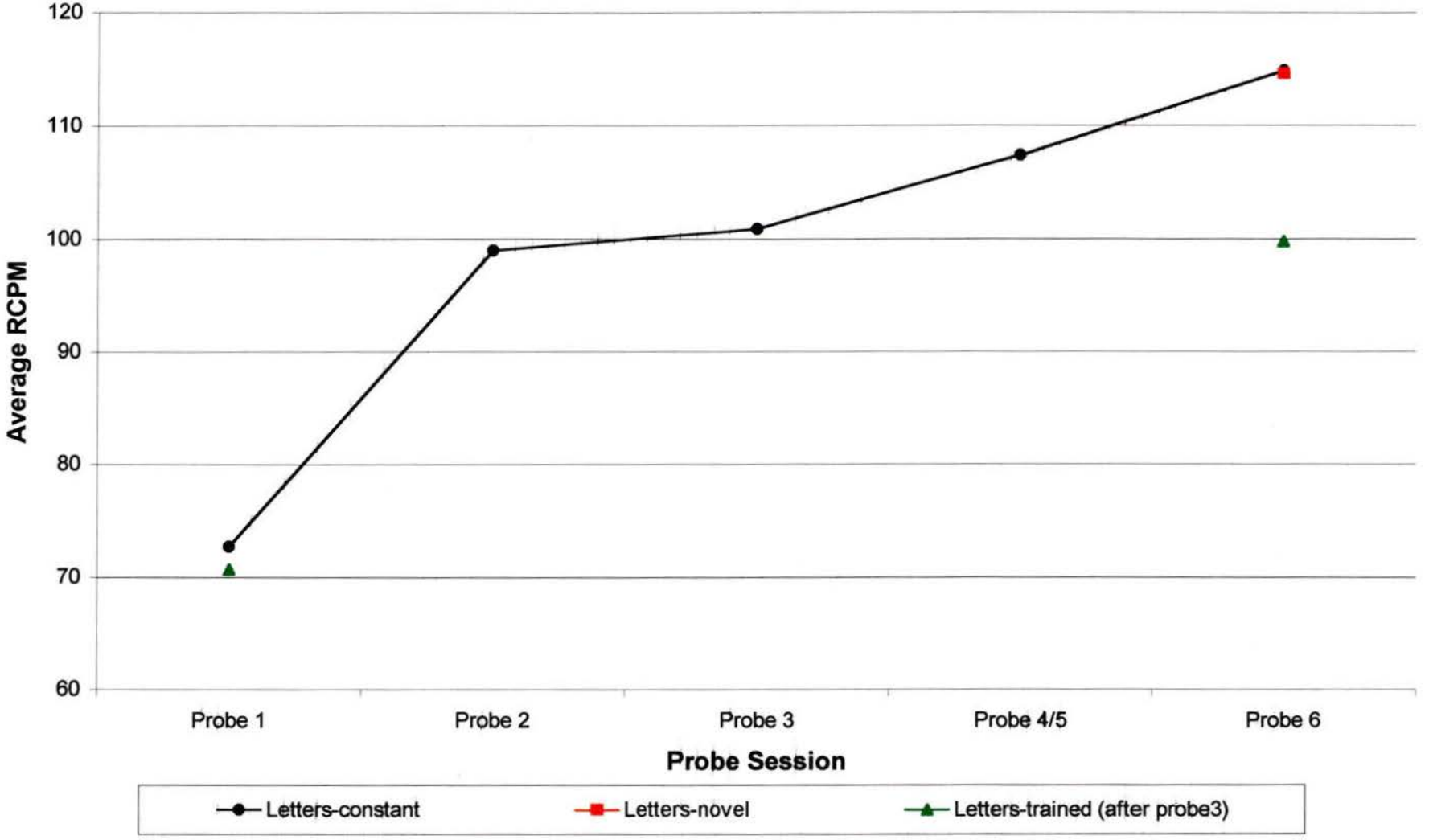


Figure 35 Probe Session Averages for the Letter Decks
Participant 3: Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained letter deck in each probe session

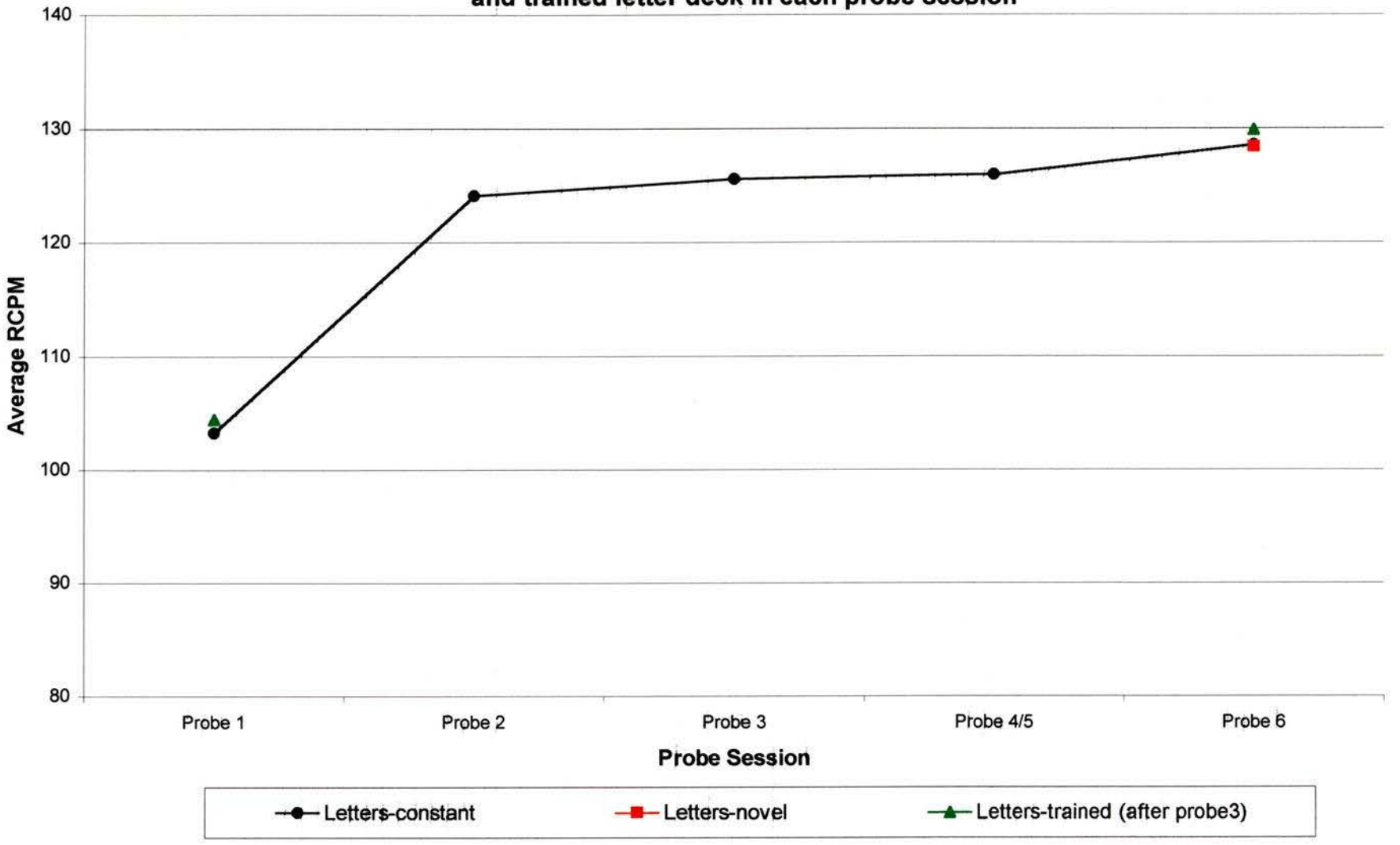


Figure 36 Probe Session Averages for the Letter Decks
Participant 4: Same/Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained letter deck in each probe session

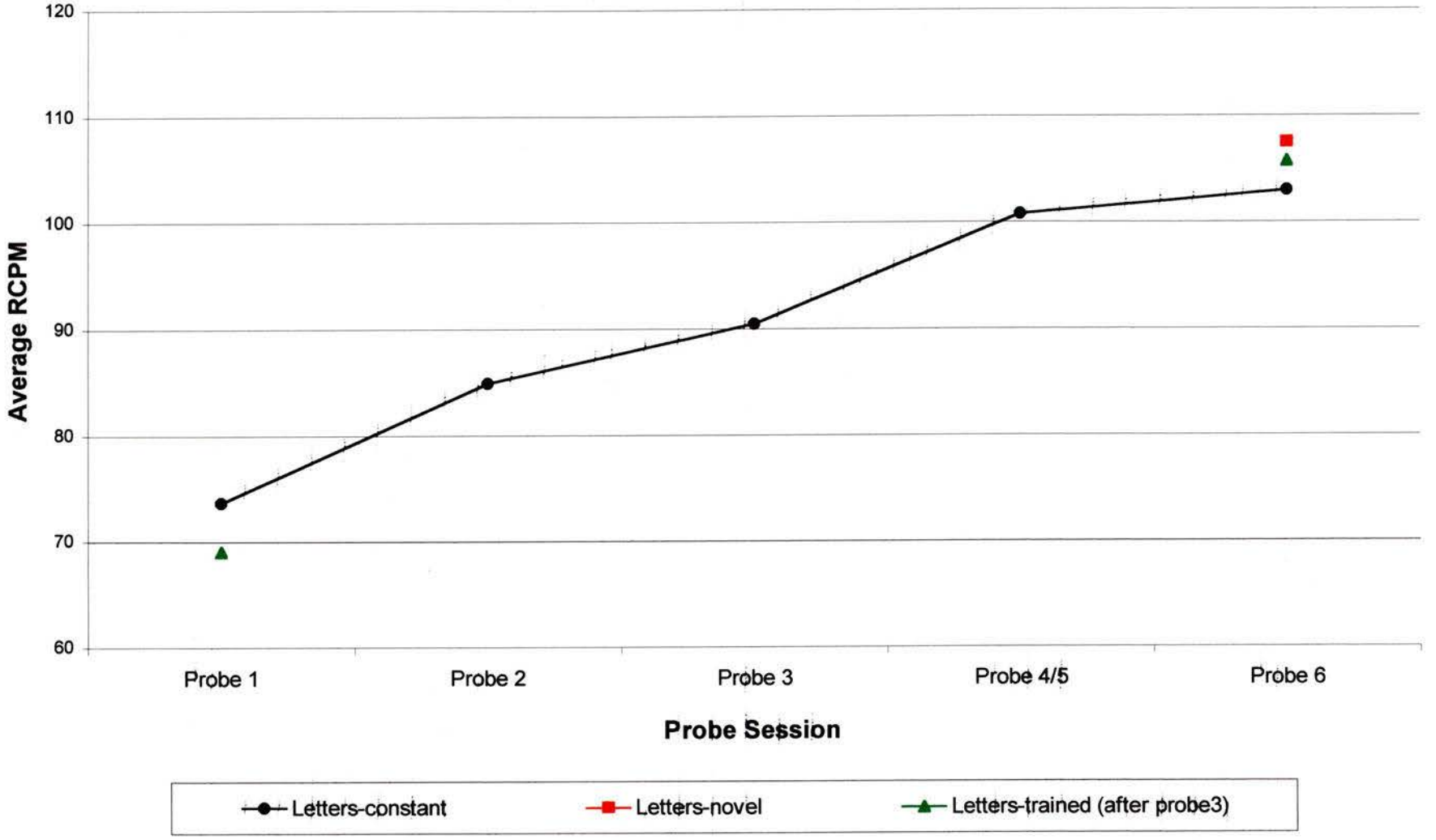


Figure 37 Probe Session Averages for the Synonym vs. Antonym Decks
Participant 1: Same/Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained synonym vs. antonym deck in each probe session

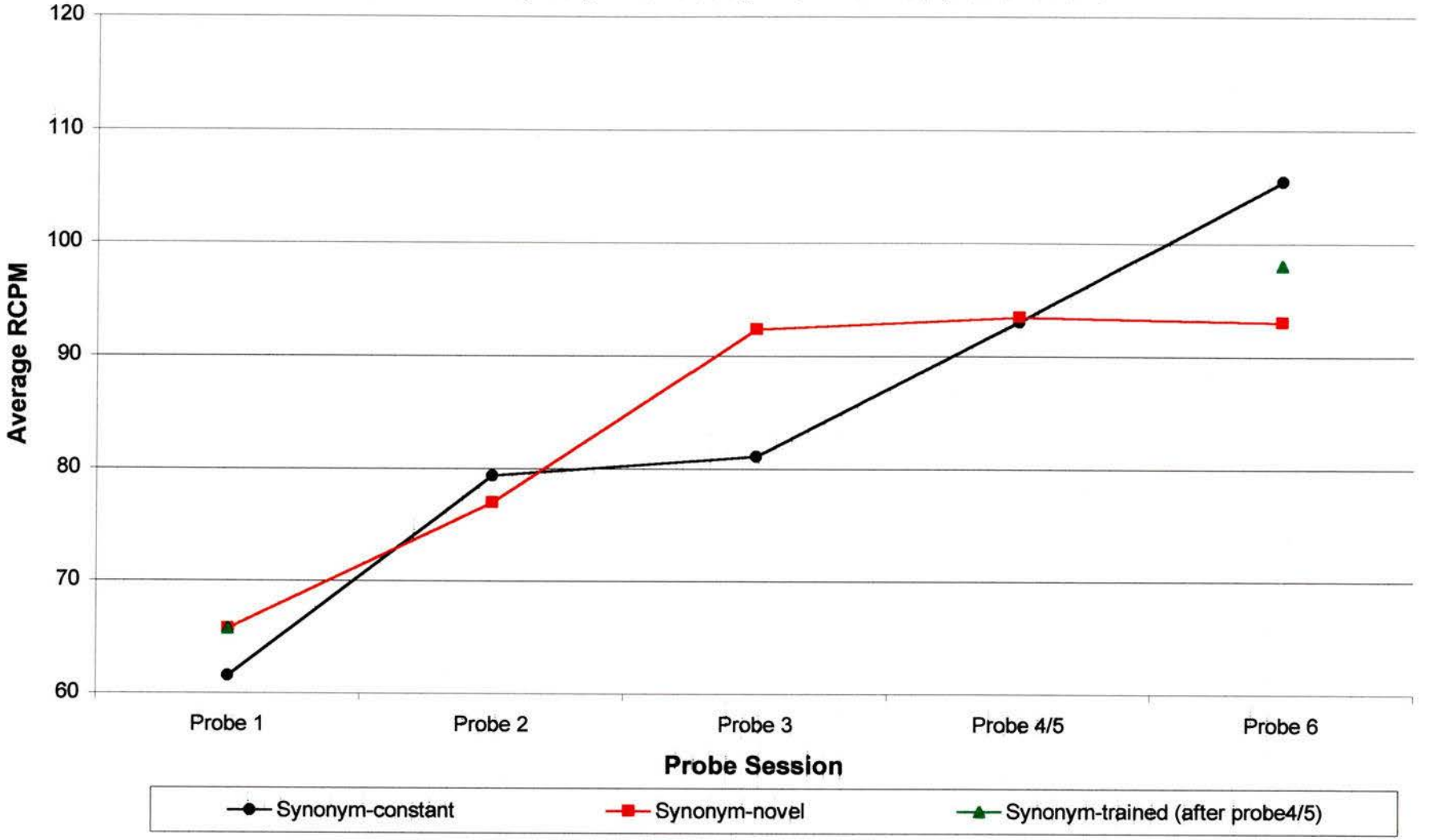


Figure 38 Probe Session Averages for the Synonym vs. Antonym Decks
Participant 2: Variable Deck Condition
Each point represents the RCPM for the constant, novel
and trained synonym vs. antonym deck in each probe session

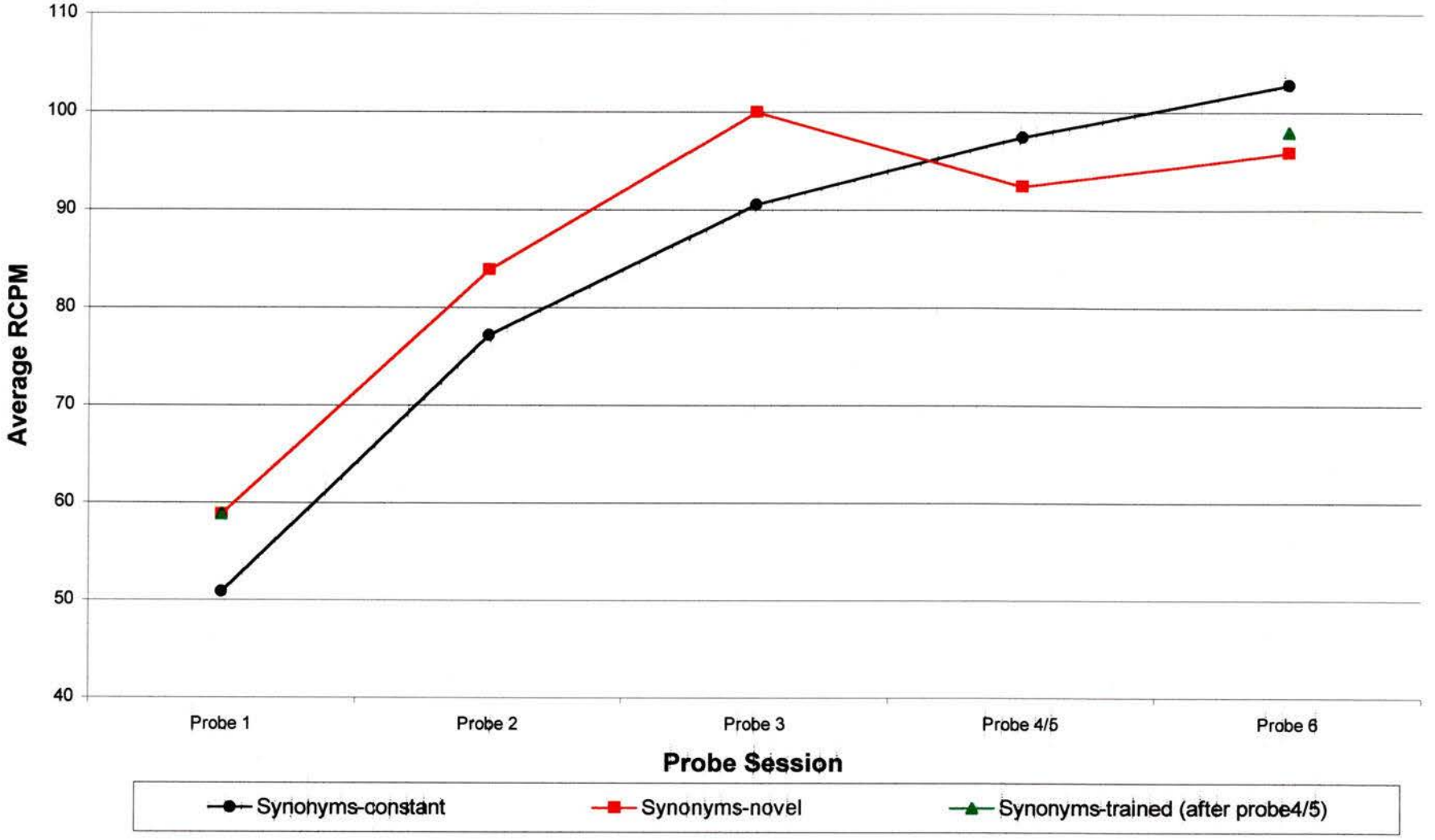


Figure 39 Probe Session Averages for the Synonym vs. Antonym Decks
Participant 3: Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained synonym vs. antonym deck in each probe session

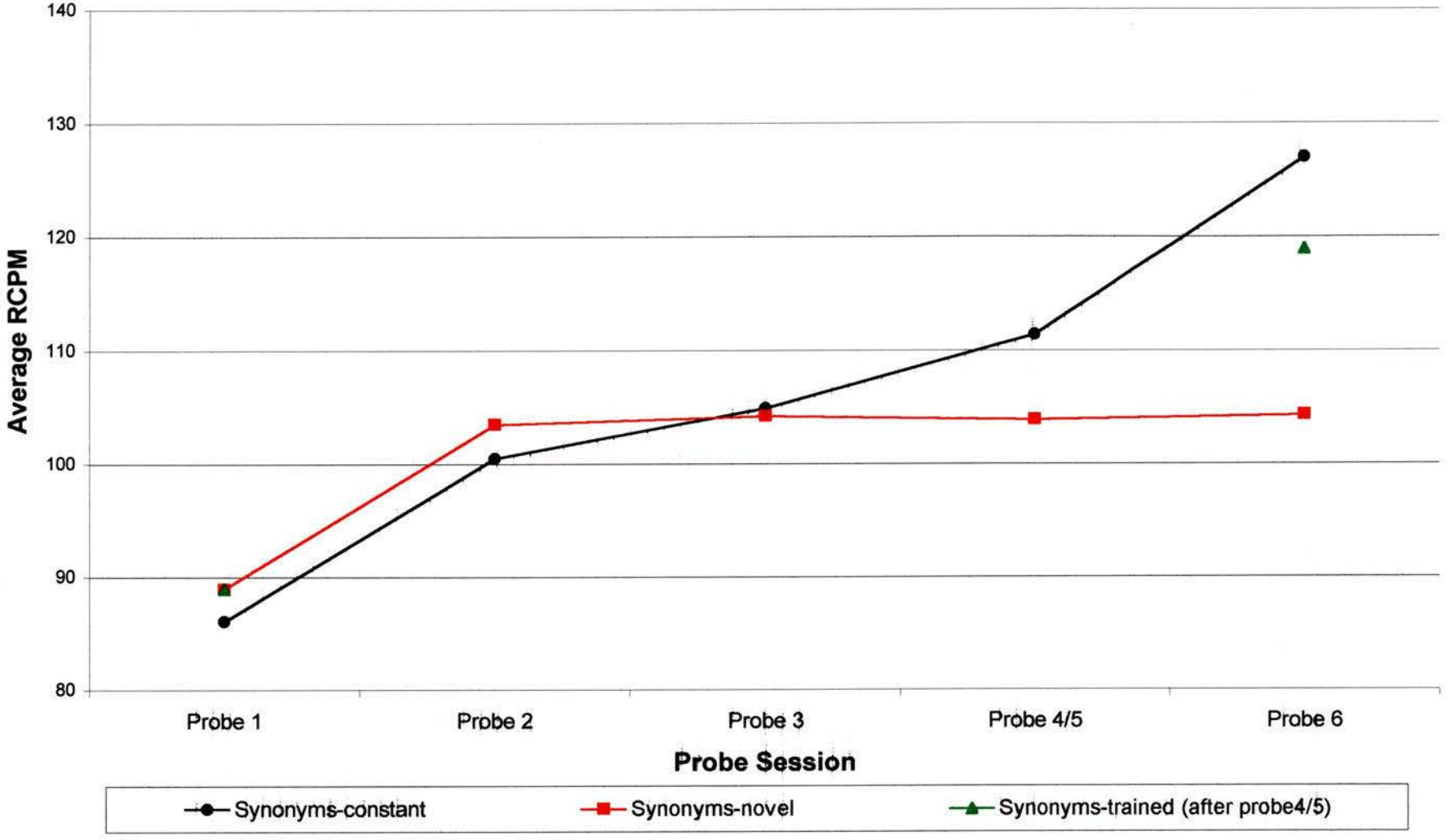


Figure 40 Probe Session Averages for the Synonym vs. Antonym Decks
Participant 4: Same/Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained synonym vs. antonym deck in each probe session

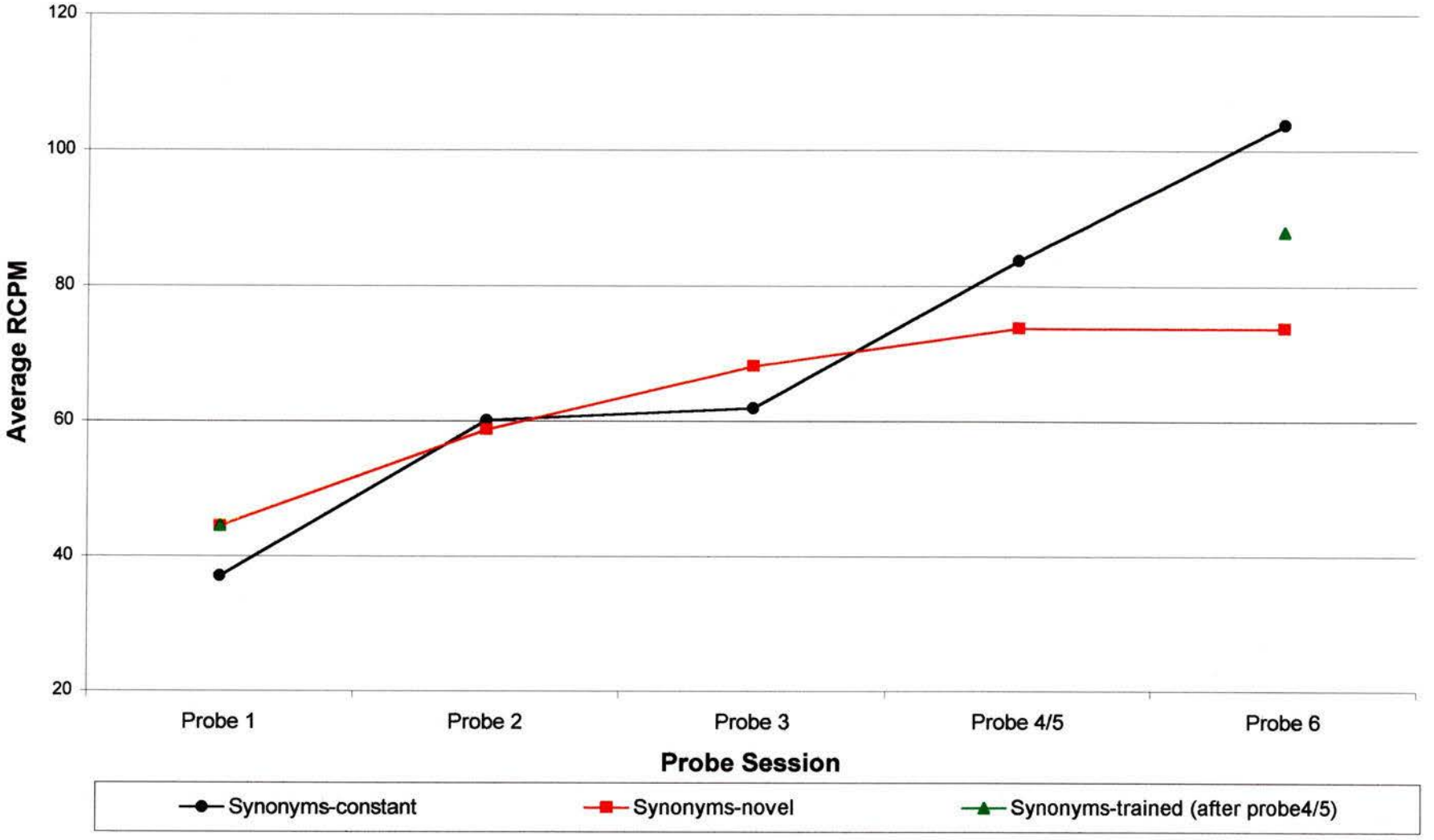


Figure 41 Probe Session Averages for the Sentences Decks
Participant 1: Same/Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained sentences deck in each probe session

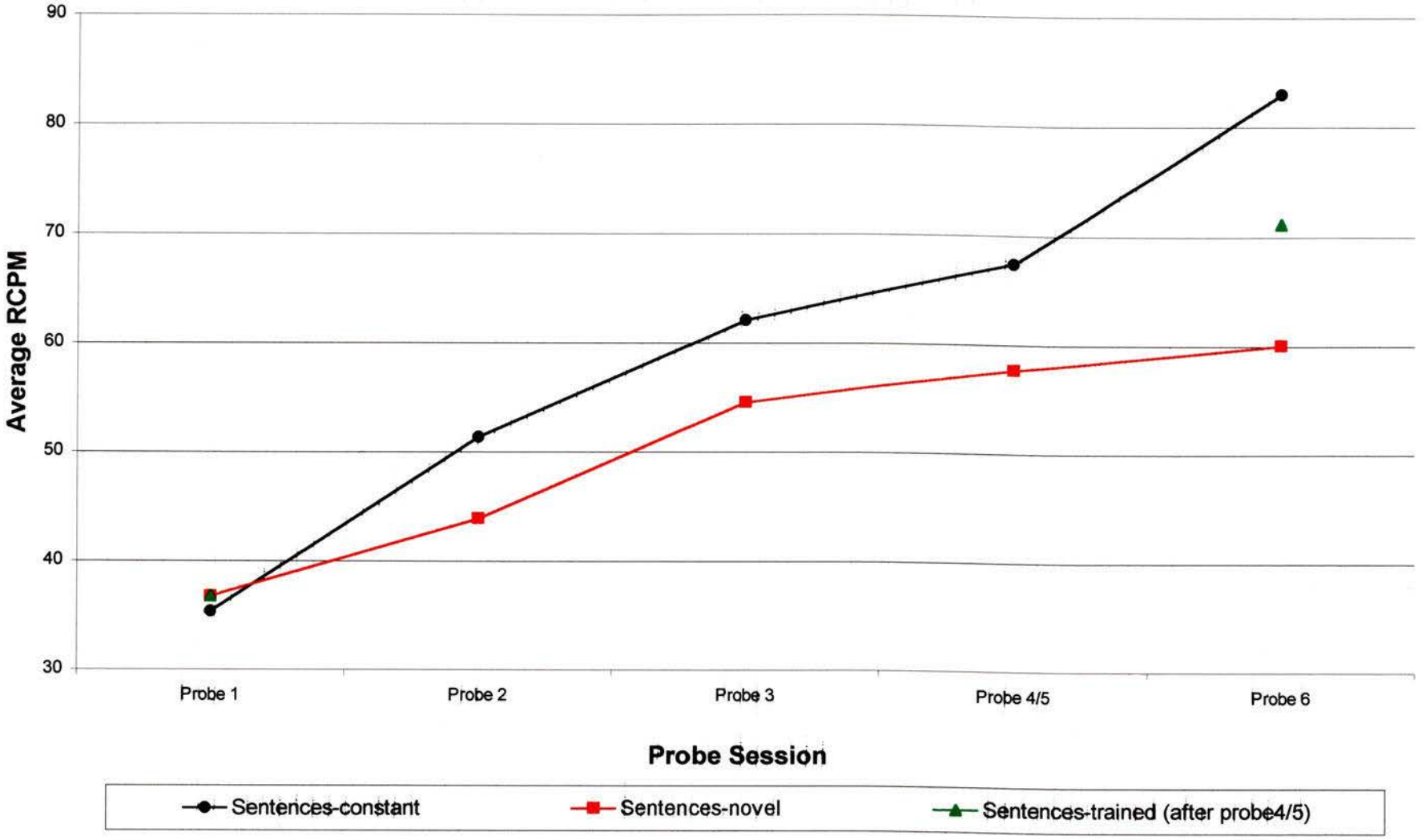


Figure 42 Probe Session Averages for the Sentences Decks
Participant 2: Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained sentence deck in each probe session

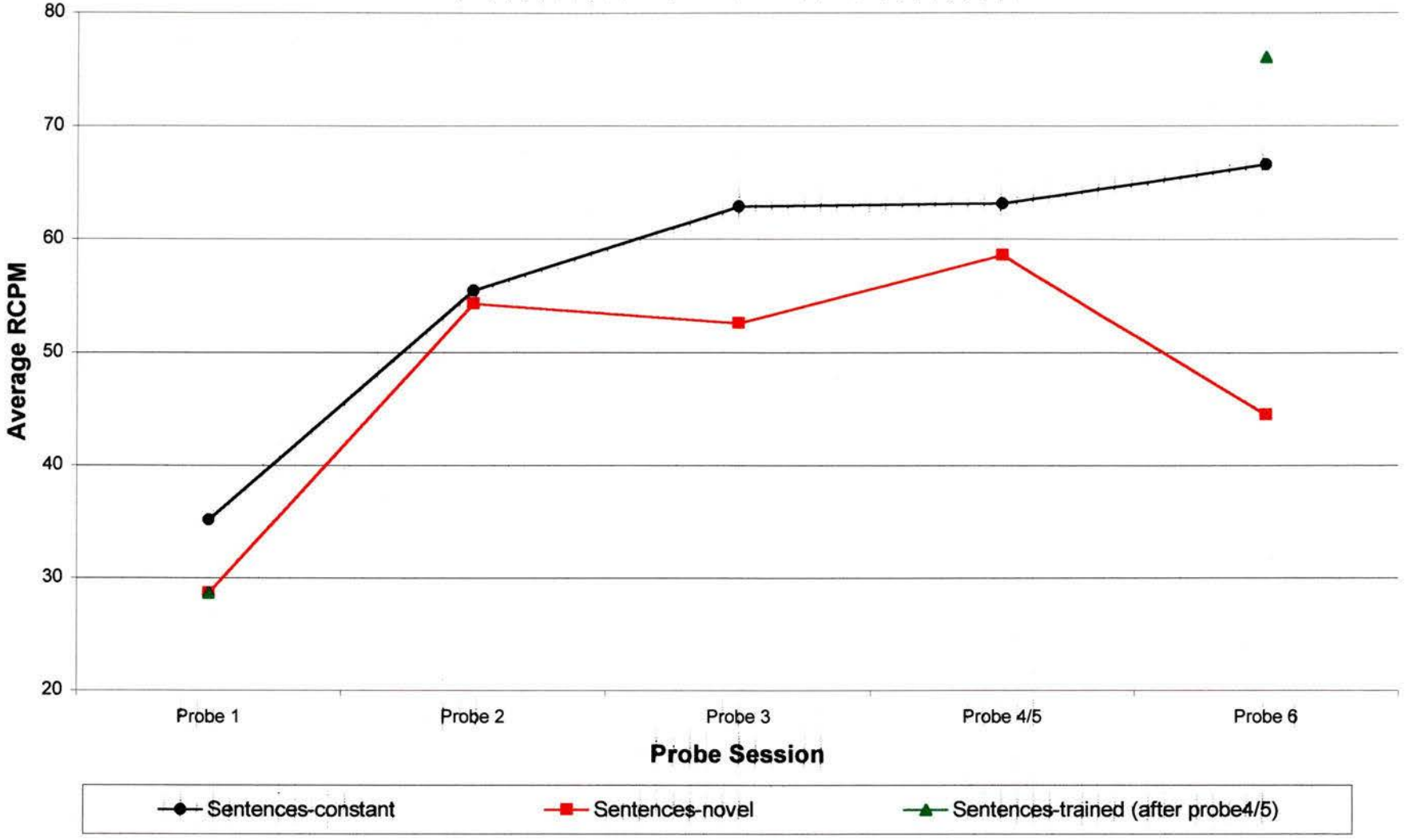


Figure 43 Probe Session Averages for the Sentences Decks
Participant 3: Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained sentence deck in each probe session

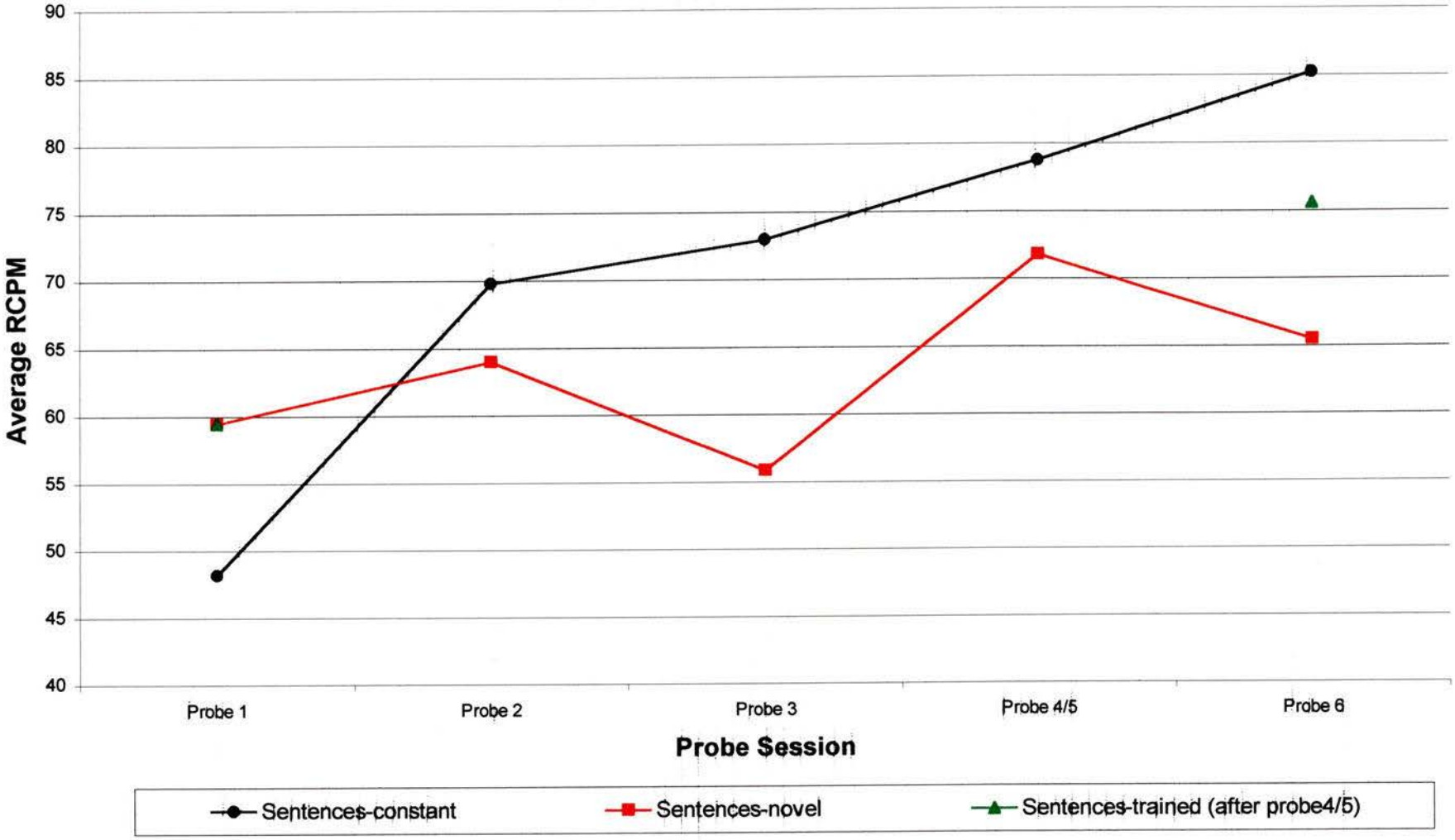
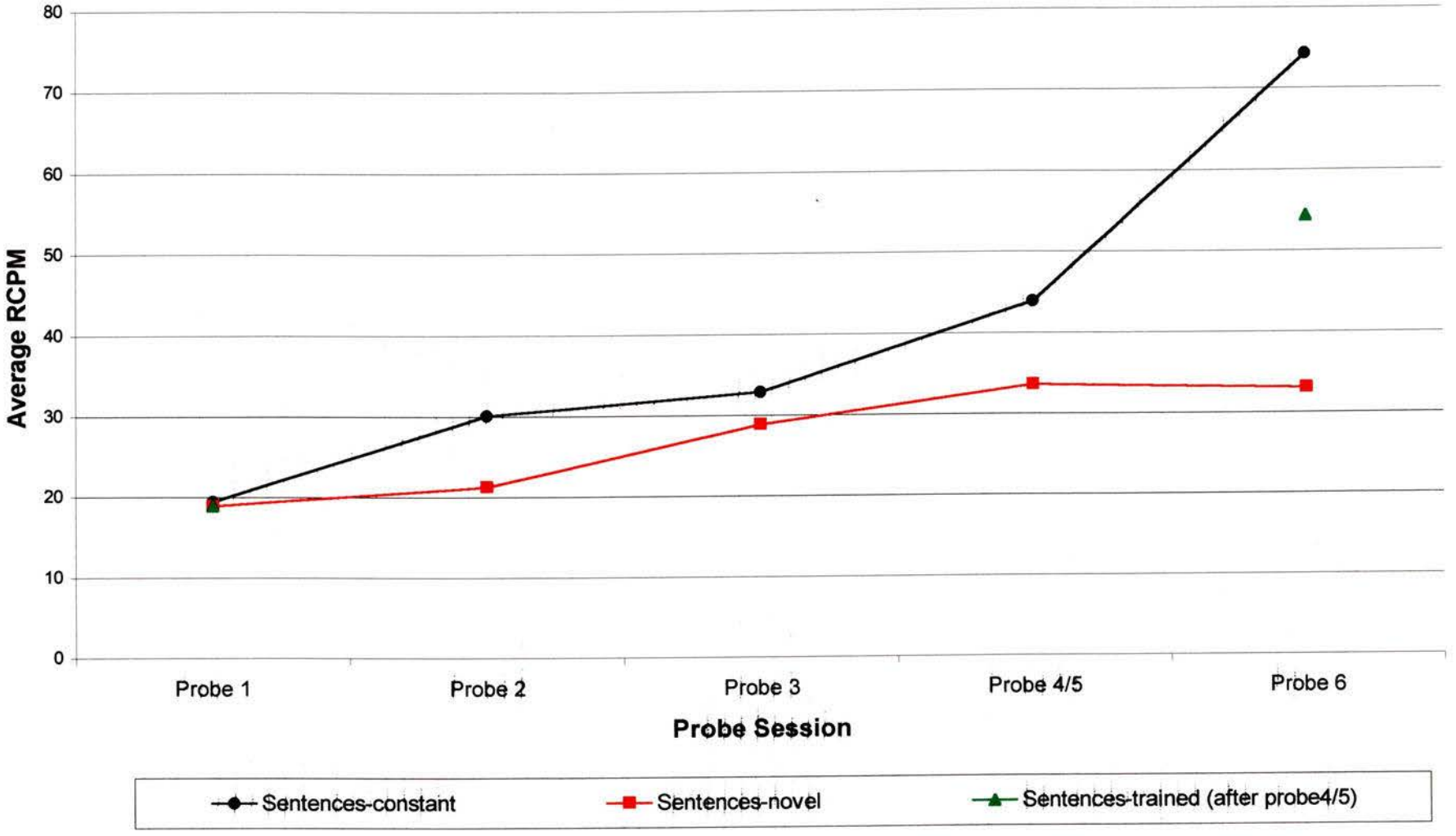


Figure 44 Probe Session Averages for the Sentences Decks
Participant 4: Same/Variable Deck Condition
Each point represents the RCPM for the constant, novel and trained sentences deck in each probe session



Appendix H

The following series of graphs (1 per participant) illustrate the Probe Session 4 (Right hand) and Probe Session 5 (Left hand) Rates for the Homonyms, Letters, Synonyms, and Sentences for each participant. Each plotted point represents the rate correct per minute (RCPM) averaged over 5 trials for each task block, with 1 block per deck per session for the Right and Left hand.

Figure 45 Probe Session 4 and 5 Rates for the Right and Left Hand
Participant 1: Same/Variable Deck Condition
Each point represents the RCPM averaged over 5 trials for each task block, 1 block per deck per session, for the right and left hand.

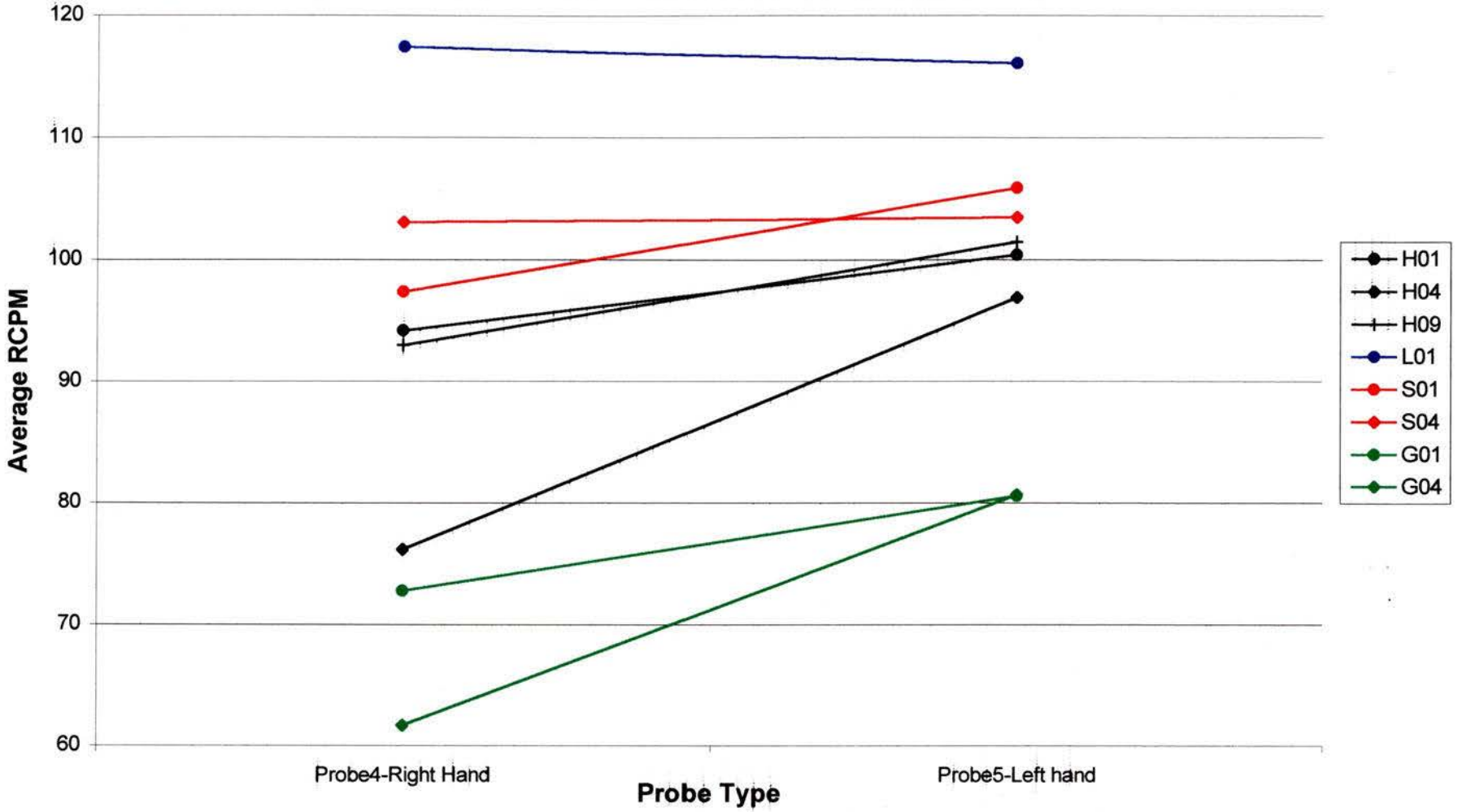


Figure 46 Probe Session 4 and 5 Rates for the Right and Left Hand
Participant 2: Variable Deck Condition
Each point represents the RCPM averaged over 5 trials for each task block. 1 block per deck per session. for the right and left hand.

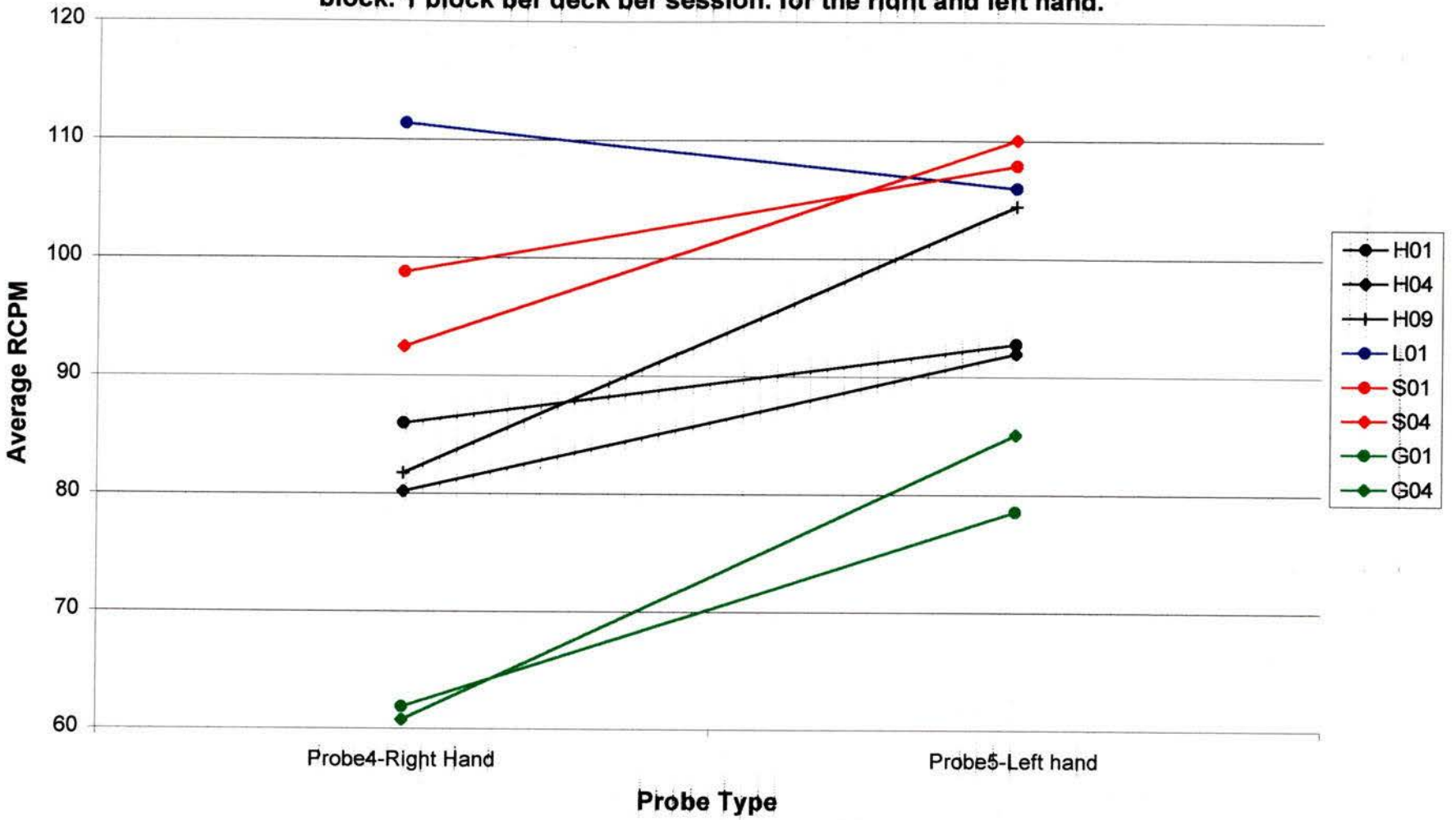


Figure 47 Probe Session 4 and 5 Rates for the Right and Left Hand Participant 3: Variable Deck Condition
Each point represents the RCPM averaged over 5 trials for each task block, 1 block per deck per session, for the right and left hand.

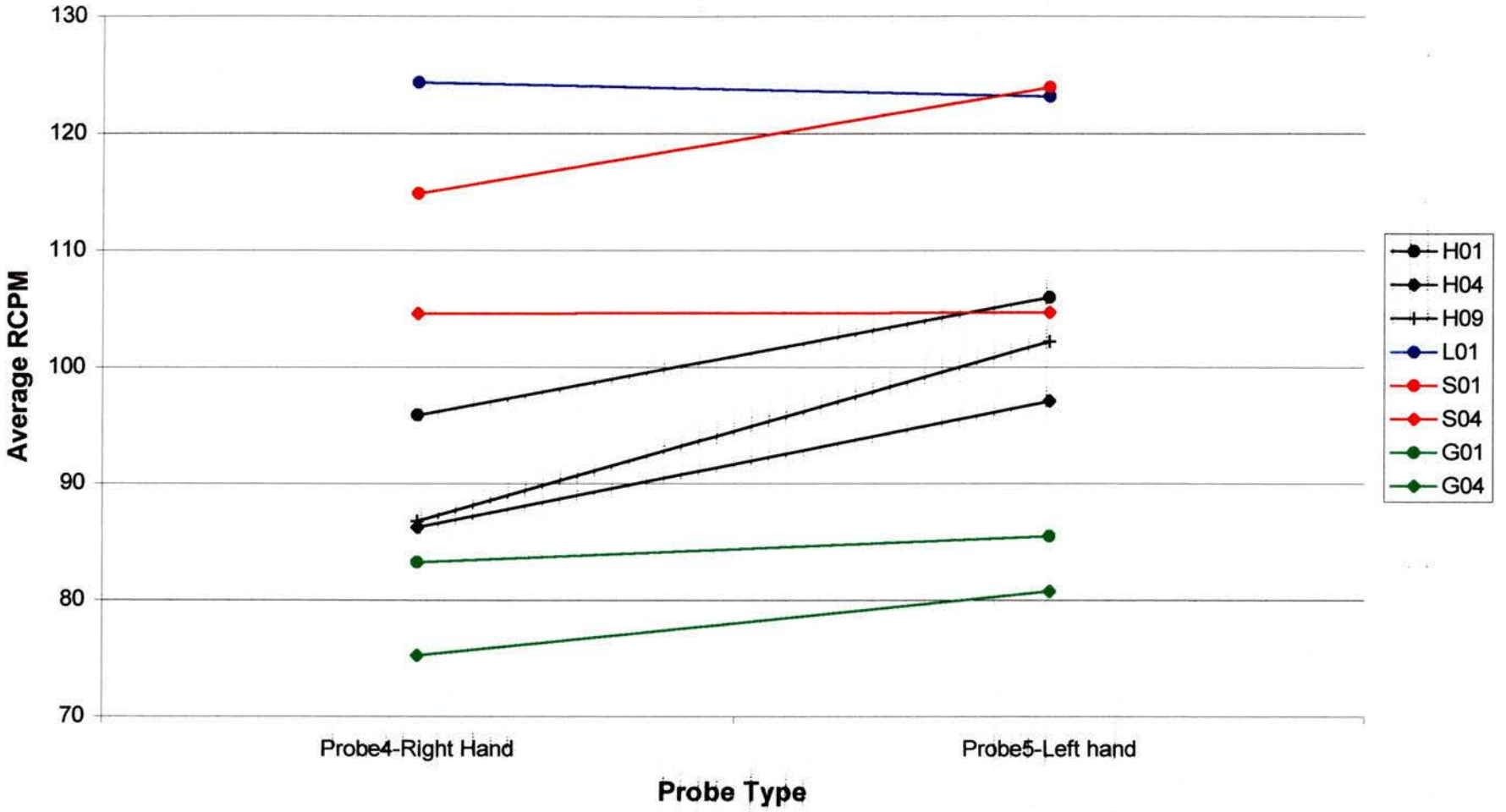
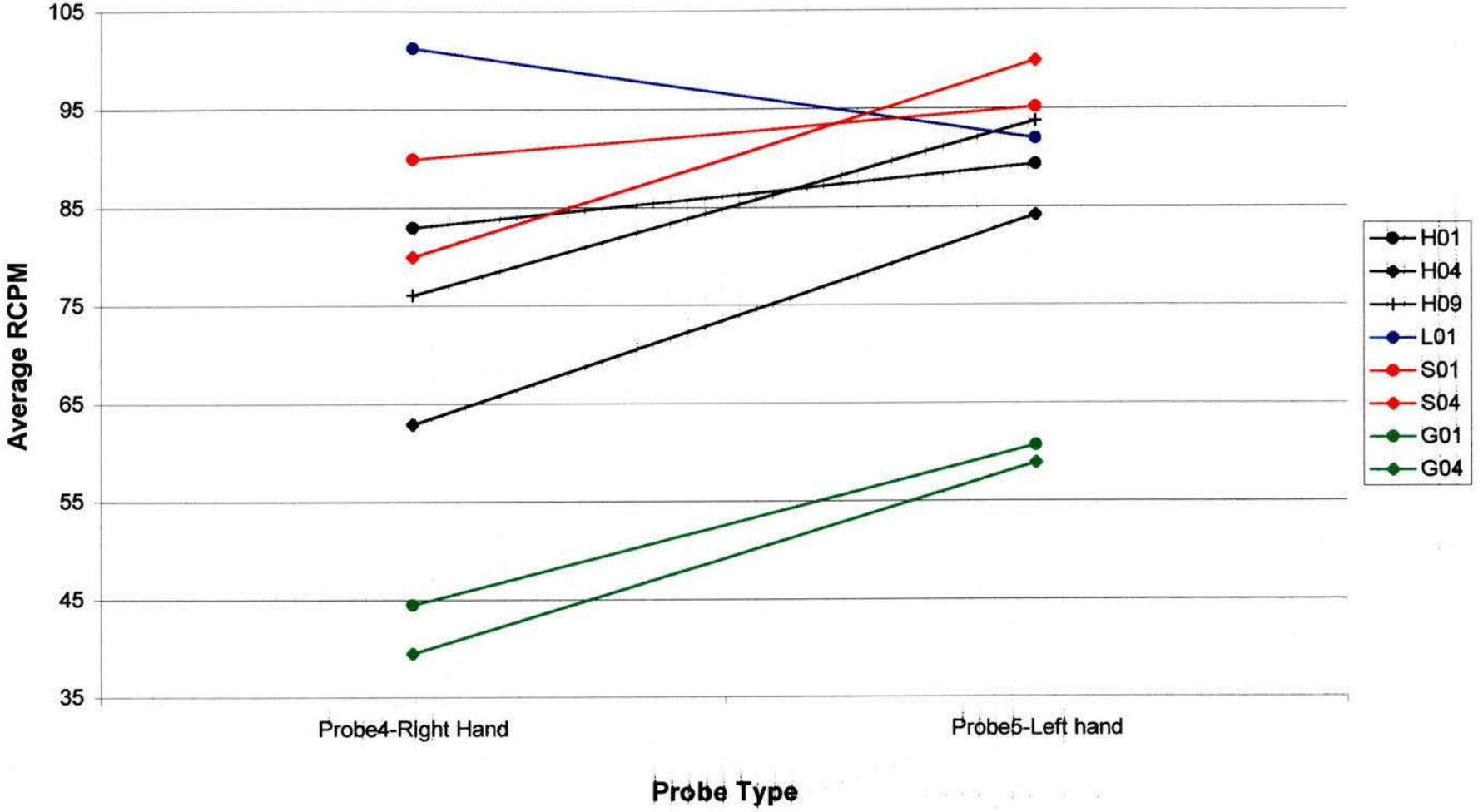


Figure 48 Probe Session 4 and 5 Rates for the Right and Left Hand Participant 4: Same/Variable Deck Condition Each point represents the RCPM averaged over 5 trials for each task block, 1 block per deck per session, for the right and left hand.



Appendix I

The following series of graphs (1 per participant) illustrate the Probe Session 6 Rates for the Homonyms, Letters, Synonyms, and Sentences for each participant. Each plotted point represents the rate correct per minute (RCPM) averaged over 5 trials for each task block, with 1 block per deck per session for the Right and Left hand.

Figure 49 Probe Session 6 Rates for the Right and Left Hand
Participant 1: Same/Variable Deck Condition
Each point represents the RCPM averaged over 5 trials for each task block, 1 block per deck per session, for the right and left hand.

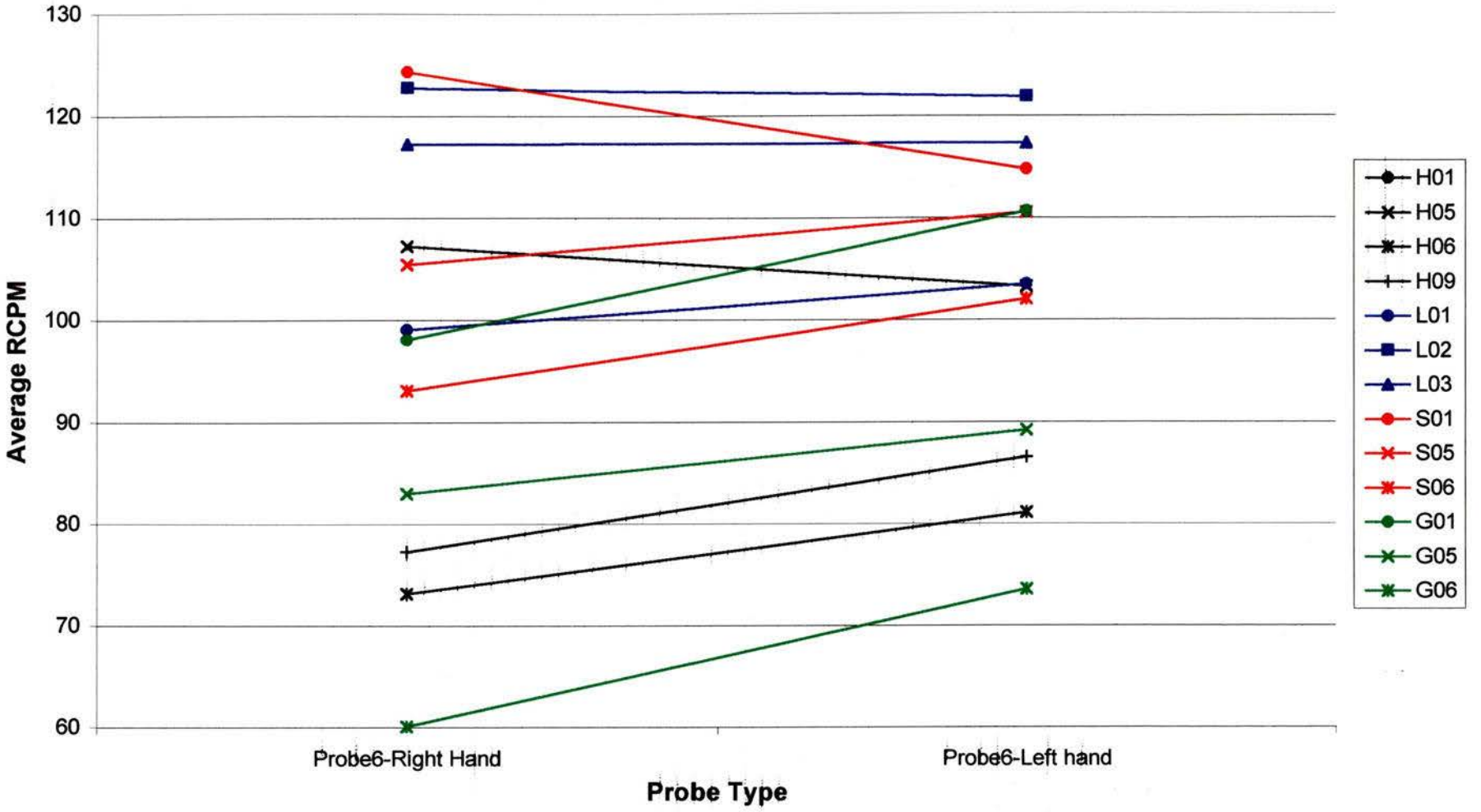


Figure 50 Probe Session 6 Rates for the Right and Left Hand
Participant 2: Variable Deck Condition
Each point represents the RCPM averaged over 5 trials for each task block, 1 block per deck per session, for the right and left hand.

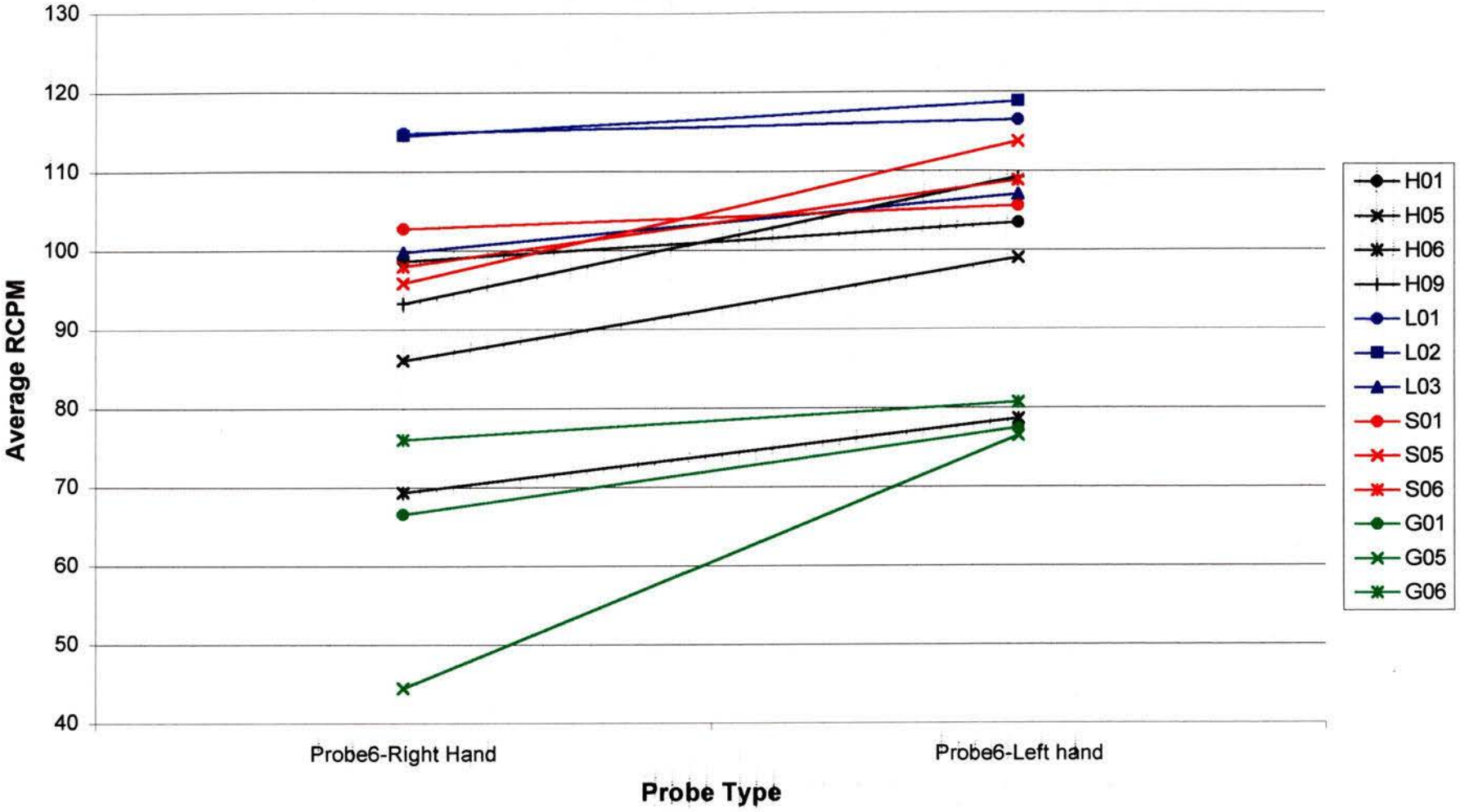


Figure 51 Probe Session 6 Rates for the Right and Left Hand
Participant 3: Variable Deck Condition
Each point represents the RCPM averaged over 5 trials for each task block, 1 block per deck per session, for the right and left hand.

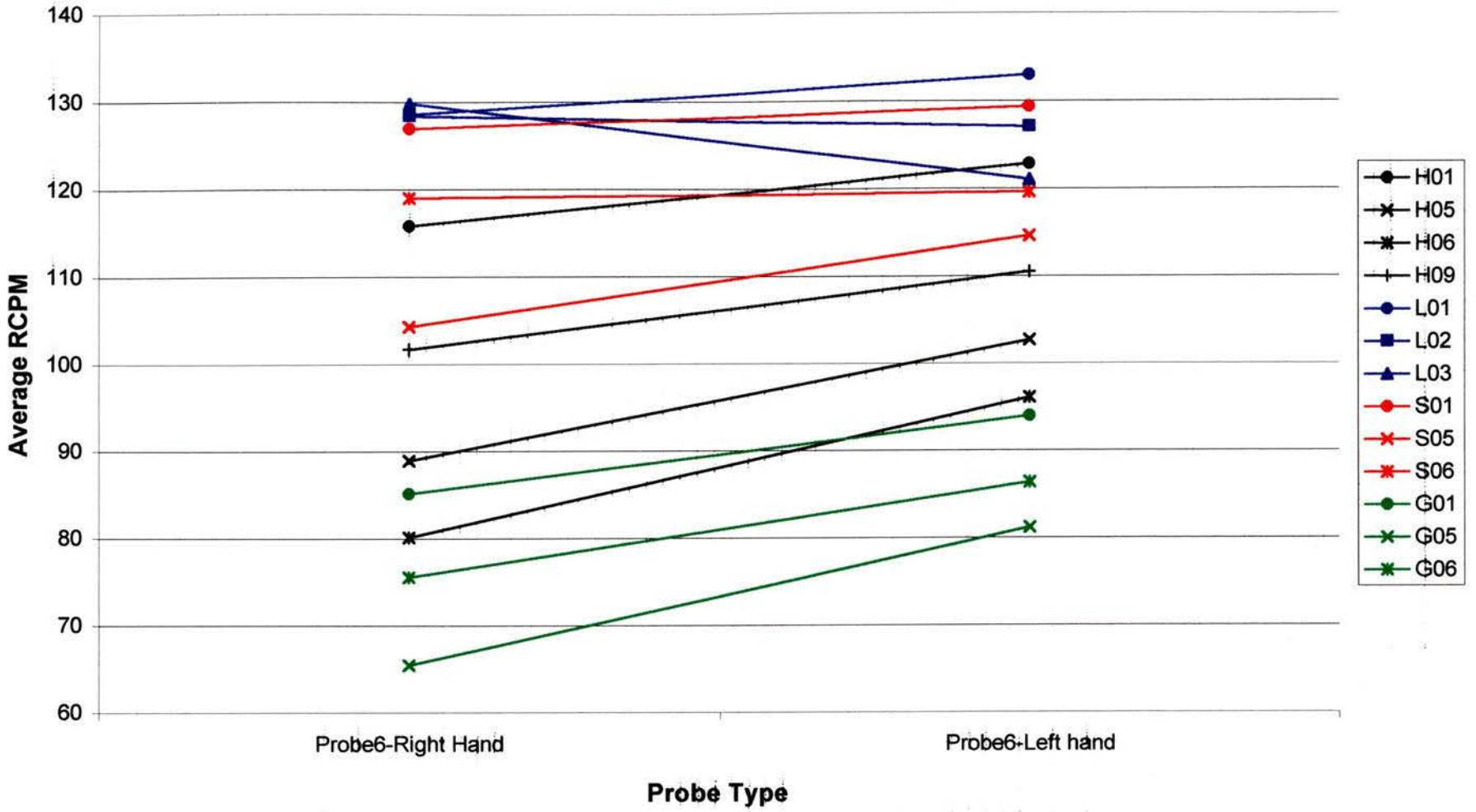
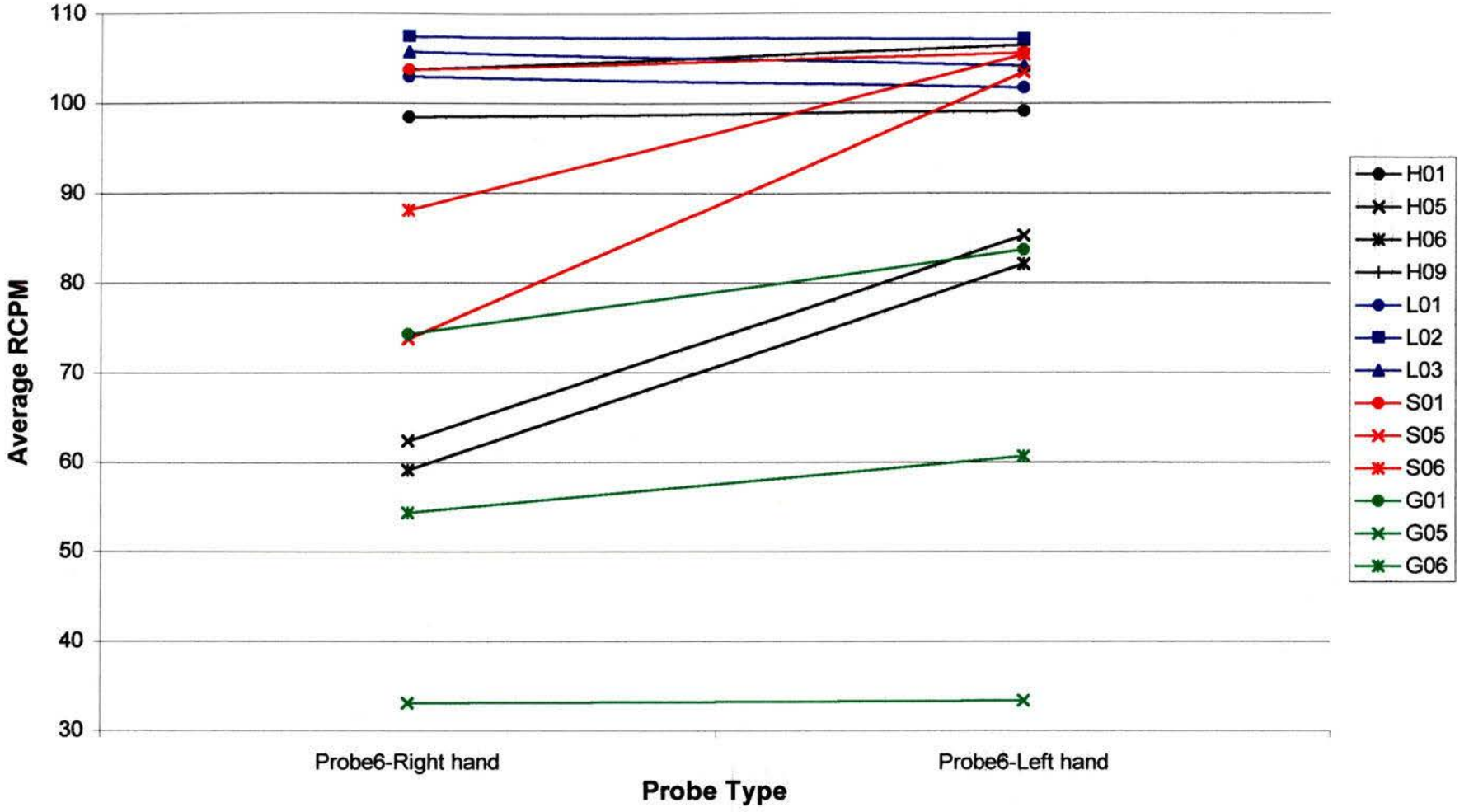


Figure 52 Probe Session 6 Rates for the Right and Left Hand
Participant 4: Same/Variable Deck Condition
Each point represents the RCPM averaged over 5 trials for each task block, 1 block per deck per session, for the right and left hand.



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Speeded Discrimination Training, Fluency, and Generalization in the Laboratory:

Training fluency and promoting generalization using Choice Reaction Time (CRT) Tasks

Author 

Chris Deborah Peters

November 24th, 2000