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Measuring Infant Attachment Security in Rhesus Macaques (*Macaca mulatta*): Adaptation of the Attachment Q-set

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Abstract

John Bowlby defined offspring-parent *attachment* as a relationship in which an infant or child uses one or a few preferred adults as a secure base from which to explore and as a haven of safety. He defined attachment *security* in terms of confidence in the adult's availability and responsiveness and the smooth organization of exploration and proximity seeking. Developmental psychologists have found this perspective productive in both observational and laboratory research. At the same time, they emphasize that such a construct cannot be operationalized in terms of one or a few behaviors. Instead, naturalistic observations of human infant attachment typically employ the Q-sort method to develop the Attachment q-set (AQS), 90 behaviorally descriptive items sorted in terms of how characteristic each item is of the infant's typical behavior. Meta-analyses of research using the AQS attest to its reliability and validity. This paper reports an adaptation of the AQS to the task of assessing infant attachment security in nonhuman primates and illustrates its use. The availability of comparable measures of attachment security will contribute to an expanded understanding of patterns of attachment behavior in nonhuman primate societies and will facilitate interaction between comparative and developmental psychologists.

Keywords

Attachment Security; Infant; Q-sort; Primates (Nonhuman); Rhesus macaque

INTRODUCTION

Research on nonhuman primates played a major role in the development of modern attachment theory by John Bowlby. Bowlby relied on nonhuman primate infant-mother studies to underpin key elements of his attachment theory building a valuable bridge between comparative and developmental psychology [1987]. Unfortunately, researchers have used this bridge less and less in recent years. A major reason for this has been the lack of a measure of nonhuman primate attachment security that is consistent with the conceptualization of attachment security by human developmental psychologists [Kondo-Ikemura and Waters 1995].

Bowlby [1958; 1969/1982; 1988] conceptualized offspring-parent *attachment* as a relationship in which an infant or child uses one or a few preferred adults as a secure base from which to explore and as a haven of safety. He defined attachment *security* in terms of confidence in the adult's availability and responsiveness and the smooth organization of exploration and proximity seeking across time and context [Ainsworth and others 1978; Sroufe and Waters 1977]. Researchers have found this perspective highly productive in both observational and laboratory research [e.g., Cassidy and Shaver 1999; Waters and others 1995].

Developmental psychologists working within the Bowlby-Ainsworth tradition have focused on three aspects of the attachment secure base phenomenon: (1) the balance between exploration and proximity seeking, (2) the quality of exploratory behavior, and (3) the affective quality of transitions from contact to exploration and from exploration to contact. Infants confident in their mother's availability are neither overly dependent nor indifferent to the mother's location and activity. They explore and play confidently, intermittently monitor and adjust to mother's location and behavior during excursions away from her. Secure infants are comfortable in contact. They approach and make contact smoothly. They mold to the mother's body and are comfortable enough to engage in playful exploration of the mother's body or active visual exploration of the environment while held. In contrast, insecurely attached infants often show distress in contact, are clingy or fussy, approach and initiate contact hesitantly, or remain unduly distant. Insecure infants also show conflict behavior in transitions from mother; their exploration is disorganized and lacks spontaneity. Attachment researchers have demonstrated that patterns of infant attachment security reliably predict a wide range of social competences in childhood and adolescence such as appropriate responses to social contexts and the absence of inappropriate externalizing or internalizing behaviors [e.g., McCartney and others 2004].

When conceptualized in terms of expectations of availability and responsiveness and competent use of a secure base, attachment security is too behaviorally complex and context-dependent to be operationalized in terms of the frequency or duration of one or a few behaviors such as approach to a mother, proximity, or physical contact. Instead, it is inferred from the organization of a broad suite of behavior across time and in relevant contexts [Sroufe and Waters 1977]. Accordingly, developmental psychologists have measured individual differences in secure base use (i.e., attachment security) in laboratory and naturalistic settings by focusing on the organization of multiple behaviors across time and context [e.g., DeMulder and others 2000].

Primatologists also acknowledge the continuing value of Bowlby's attachment theory [Suomi 1995]. The primary obstacle to their interacting productively is not theoretical but methodological. Primatologists interested in infant-mother relationships have most often operationalized attachment in terms of traditional ethological discrete behavioral variables such as time in contact or proximity, nipple rejection, and approaches and leaves [e.g., Hinde and Spencer-Booth 1967; Schino and Troisi 2001]. With few exceptions [e.g., Andrews and Rosenblum 1991; Stevenson-Hinde and others 1980; Weaver and de Waal 2002] primatologists have been cautious about straying from this tradition.

Having a measure of nonhuman primate attachment security comparable to measures used in human attachment research would help rebuild the bridge between comparative and developmental psychology expanding the knowledge and perspectives of these disciplines. Nonhuman primate researchers could design studies that address questions of interest to comparative psychologists, developmental psychologists, and primatologists alike in which attachment security can act as an outcome variable, a correlate, a moderator, or a predictor variable. For example, what aspects of maternal behavior or physiology (e.g., hormones,

stress responses) are related to individual differences in offspring attachment behavior? What role might inherited rank play in individual differences in attachment security or individual differences in attachment security play in acquired rank? Does attachment security moderate stress as measured by change in heart rate or cortisol levels? In Old World monkey species whose males transfer from the natal group, do daughters and sons differ in their attachment security? Is the ability to assess complex social interactions related to differences in attachment security? Answers to such questions would add simultaneously to our understanding of nonhuman primate societies and to our understanding of the function of human attachment behavioral systems.

The two most widely used measures of attachment security in children are the Strange Situation Protocol (SSP) and the Attachment Q-Set (AQS). The SSP is a formal 8-episode experimental protocol requiring removing and reintroducing mothers, their infants, and strangers at timed intervals [Ainsworth and others 1978]. The AQS is a methodology designed especially for less restrictive conditions than the SSP, especially for naturalistic contexts [Waters and Deane 1985]. Meta-analyses on 139 AQS studies with 13,835 children testing the AQS's convergent, predictive, and discriminant validity confirmed its validity; the study's authors describing the AQS as a gold standard for measuring attachment security [van IJzendoorn and others 2004].

In the following sections we first describe the Q-sort method in general, defining terms and providing a clear picture of how the method is applied. We then provide illustrations of the method's use to date in macaque attachment research addressing questions of reliability and validity. Finally we summarize the advantages and disadvantages of the Q-sort method for use with nonhuman primates.

THE Q-SORT METHOD

The Q-sort method describes an individual in terms of a particular construct such as attachment security in a form suitable for quantitative comparison and analysis using a large set of descriptive items related to the construct [see Block 1961 for a full description]. Originally applied to personality research, the method is equally suitable for scoring an array of behavior patterns and their contexts associated with complex constructs, and ultimately allows scoring the individual on the construct. The method is applied in five steps: (1) constructing a Q-set; (2) observation of a subject by an observer familiar with the Q-set items; (3) applying a sorting procedure to assign a score to each Q-set item to reflect how characteristic the item is of the subject's behavior during an observation (the "Q-sort"), (4) combining data from multiple observers and/or observations to increase reliability, and (5) assigning an individual a score on the overall construct.

Constructing a Q-set

A Q-set is an ethogram, a vocabulary for describing the behavior of target individuals. The researcher creates a reasonably complete list of behaviors related to the construct (Q-set items) that are expected to be observed in the setting in which data will be collected. Because many behaviors serve multiple functions and because context plays such a significant role in the meaning of behavior, separate items are created to represent the same behavior in significantly different contexts. For example, fully describing when and how an infant approaches its mother could require a half dozen or more items. The need for a comprehensive list of behaviors and contexts accounts for the fact that typical Q-sets include 50 to 100 items.

A well constructed Q-set reflects considerable knowledge of the construct's salient behaviors and how they function in combination and in relation to context. Researchers

familiar with the subjects and the construct are often consulted with respect to behaviors they would include in the Q-set. Once the provisional Q-set is established, it is tested in pilot observations to confirm that the items are unambiguous, comprehensive, and observable in the data collection setting. After necessary adjustments are made, the Q-set is considered complete.

Observation

The Q-sort observer's task is to describe a target individual's behavior during an observation in terms of the Q-set items. Because observers are familiar in advance with the Q-set items, they recognize key behaviors as "scorable" and during the sorting process (explained below) the items themselves serve as powerful retrieval cues. Some observers find it useful to use a checklist or informal notes to serve as reminders of behaviors or interactions that seem particularly important to recall during sorting. We have found that reliable assessment of a free-ranging infant macaque's skill in using its mother as a secure base typically requires observation time of approximately 30 minutes [Warfield 2003]. In captivity, where social interactions often occur at higher frequencies, briefer observations may suffice.

Video recording—Q-sorts can be based on real-time or videotaped observations. Interactions in nonhuman primate infant-mother dyads are often rapid and subtle; videotaping allows the observer to look at the interactions in slow motion or take a second look at interactions about which the observer is initially uncertain. Another advantage of videotaped observations is that they allow observers to return to the videotape archive to include assessment of a behavior that was not initially thought relevant to the construct.

Sorting Q-set items

The observer uses the Q-sort procedure to assign each Q-set item a score that rates how characteristic or uncharacteristic the item was of the individual's behavior during the observation. The term "characteristic" refers not to the frequency or duration of the behavior but to whether it is central to the organization of the individual's behavior, whether it would distinguish this individual among others, whether the individual appears highly motivated to perform the behavior. For example, during a 30-minute observation an infant might spend 20 minutes dozing sleepily on its mother but once awake actively begins to explore away from its mother. The observer might rate the "explores actively" item as characteristic even though the target individual didn't spend the majority of its time engaged in exploration. Most observers find they quickly become comfortable making and reaching agreement on such judgments.

The remainder of this section provides details of the sorting procedure. Figure 1 summarizes the 3-step procedure for sorting a 90-item Q-set. In Step 1, the Q-set items are sorted in a preliminary way into three categories. On the left are placed items that are *Uncharacteristic* of the target individual. In the middle are placed items that would not distinguish the target individual among others. On the right are placed items that are *Characteristic* of the target individual. It is not necessary to place equal numbers of items in each pile at this stage. Items can move closer to or farther from the middle as the sorting is refined in subsequent steps.

In Step 2 the sorter refines decisions about how characteristic each item is of the target individual by subdividing the three initial piles into nine piles arrayed from *Most Uncharacteristic* on the far left to *Most Characteristic* on the far right. This is accomplished by sorting the items in the left (*Uncharacteristic*) pile into three piles, with the very most uncharacteristic items on the far left. Then the middle pile is subdivided into three piles, with mildly uncharacteristic items on the left, mildly characteristic items on the right, and

the remainder in the middle. And finally the items in the right (*Characteristic*) pile are subdivided into three piles, with the very most characteristic items on the far right.

The farther an item is placed from the center pile the “stronger” the statement about this individual during the observation. Placing an item in pile 7, 8, or 9 suggests that this was characteristic of the target individual: a salient descriptor of the individual’s typical behavior. Placing an item in pile 3, 2, or 1 suggests that such behavior was uncharacteristic of the target individual: antithetical to its typical behavior. Sorters typically describe the items in the center (piles 4, 5, and 6) as the ones about which they have least to say regarding the target individual. Behaviors that do not occur for lack of opportunity (e.g., the mother is not visible during the observation) or which offset one another (e.g., the infant follows its mother six times and fails to follow her six times) are also placed in the middle.

With the items sorted into nine piles ranging from *Most Uncharacteristic* on the far left to *most Characteristic* on the far right, Step 3 creates the final pile placement distribution, generally by equalizing the number of items in each pile. Beginning with the items in pile 1, the sorter selects the required number of items. Remainders are mixed with the items in the adjacent pile closer to the center (i.e., pile 2). If too few items are initially in pile 1, the sorter combines them with items from the adjacent pile closer to the center (i.e. pile 2). The sorter repeats this procedure for piles 2, 3, and 4, selecting the items necessary to fill a pile and moving any remainder closer to the center of the sort. Then, working from the opposite end of the sort, the sorter fills piles 9, 8, 7, and 6. When the remainder from pile 6 are placed in pile 5 it will necessarily contain the correct number of items. This process of equalizing item numbers from the outside piles toward the center takes advantage of the fact that items in the outer piles are most relevant (positively and negatively) to describing the target individual and thus are easiest to make decisions about.

The sort completed, each item in pile 1 is assigned a score of 1, each item in pile 2 is assigned a score of 2, etc. As illustrated in Table 1, the scores are then written as an array of n (number of items in the Q-set) scores, from Item 1 to Item n . This array is one observer’s Q-sort description of the target individual.

Q-sets are ordinarily designed to be sorted into a rectangular distribution: 9 piles with equal numbers in each pile. If the number of items is not equally divisible by 9, the number of items in the middle pile is increased to include the remainder. Some researchers prefer to sort the items into a quasi-normal distribution. This entails making finer distinctions among a smaller number of highly salient items assigned to piles at the extremes of the sort and fewer distinctions among the larger set of items placed in the middle piles. Either format is acceptable and has nothing to do with meeting assumptions for statistical significance testing.

Assessing reliability

Traditional methods assess inter-observer reliability on individual items checking to see if frequencies and durations are consistent from observer to observer. In Q-sort research reliability is determined by the similarity of the n -item Q-sort descriptions provided by concurrent independent observers. Because Q-set items are sorted into a fixed distribution for each individual, the n -item arrays of scores describing a target individual have the same mean and variance for every individual; therefore, the Pearson correlation is a suitable indicator of inter-observer reliability (agreement/similarity) between observers’ Q-sort descriptions of a given individual for any one observation. With adequate training and observation time, agreement is typically in the range of $r = 0.60 - 0.80$ between pairs of observers.

Intra-observer reliability can be tested and re-tested using the same approach if observations have been videotaped. The observer can sort the same videotaped observation intermittently and the Pearson correlation calculated to ascertain the level of intra-observer reliability.

Averaging Q-sorts

To obtain a more reliable composite description of a target individual, researchers often average the sorts of two or more observations. As indicated in Table 1, the sorts are combined by averaging the pile placement of each item across observations. For example, if during observation 1 a subject characteristically uses its mother as a secure base and the item is placed in pile 9 while during observation 2 the subject is generally playing away from its mother and the item is placed in pile 3, the item would be given an average pile placement of 6. By following this procedure reliability per item is enhanced. The composite Q-sort consists of the averaged pile placement of each Q-set item. This method for increasing reliability can be used with multiple observations by one observer or with observations by two or more independent observers. Note that it is the item placements that are averaged across observations to increase reliability, not the criterion Q-sort scores described in the following section.

When creating composite scores, Q-sorts should be averaged within age blocks the researcher considers developmentally consistent. For instance, if a researcher is comparing “early infancy” attachment security to “late infancy” attachment security, Q-sorts should be averaged within rather than across those categories. While composite Q-sorts increase reliability, the composite must be consistent with the research question.

Defining and scoring constructs

The Q-sort observer describes a target individual in terms of the Q-set items but does not evaluate that individual with respect to a particular construct. Scores on specific constructs are derived from comparing the Q-sort descriptions to construct definitions called Criterion Sorts.

Construct definitions (Criterion Sorts)—Before an individual can be scored on a construct, the definition of the construct must be made explicit in terms of the Q-set items. Experts transparently formalize their understanding of the construct by sorting the Q-set items to describe the behavior pattern that would receive the highest score on this construct according to the underlying theory of the construct. The term Criterion Sort reflects the fact that the experts’ consensus sort both defines the construct and serves as the criterion that would have to be met to obtain a maximum score.

The procedure for constructing criterion sorts is the same as for describing target individuals (Table 1) except that observer descriptions of a target individual are replaced by experts’ pile placements of the Q-set items. The experts make their pile placements based on their understanding of how an individual scoring highest on a construct such as attachment security would characteristically perform on each item. For example, an item such as “Departures from mother are spontaneous; infant leaves mother readily and calmly” might be placed in piles 8 or 9 if deemed highly characteristic of attachment security or in piles 1 or 2 if deemed highly uncharacteristic of attachment security. In this way, experts build a definition of attachment security item by item. The expert pile placements are averaged to yield a more reliable “consensus” criterion sort, just as observations are averaged to yield a more reliable item pile placement for a target individual’s composite Q-sort. Pairwise agreement between experts is typically quite high ($r = 0.8 - 0.9$), with sorts from as few as three experts yielding reliabilities of 0.8 or more.

Calculating construct scores using criterion sorts—An individual's score on a construct (its "Q-sort score") is based on the similarity between the observer's Q-sort description of that individual and the criterion sort description of the construct. While any number of indices could be used to assess similarity between the n-item arrays describing an individual and a construct, researchers generally compute the Pearson correlation between the n-item Q-sort description of the target individual and the similarly dimensioned criterion sort definition of the construct [Block 1961]. The correlation coefficient is used as an index of an individual's similarity to the criterion sort – its Q-sort score.

Theoretically Q-sort scores could range between +1.0 and -1.0, but in practice they rarely exceed ± 0.50 . Because the Pearson correlation is a nonlinear association index, correlations with criterion sorts may be adjusted using Fisher's r-to-z transformation. In practice this step is normally omitted because the r-to-z adjustment is trivial with Q-sort scores rarely exceeding ± 0.50 .

Summary

The Q-sort method allows researchers to reliably score individuals on complex constructs in a form suitable for quantitative comparison and analysis. It can be a useful addition to the toolkit of methods for formulating and testing hypotheses about constructs such as attachment security. However, Q-sorting is not intended to be an alternative to written narratives, video recordings, or other traditional methods when making initial observations of relatively unstudied species or familiar species in novel contexts.

THE Q-SORT METHOD IN ATTACHMENT RESEARCH WITH MACAQUES

This section illustrates the use of the Q-sort method to measure attachment security in nonhuman primates in a manner that parallels the measurement of the attachment security construct used in human infant research more closely than previously accomplished using frequency and duration measures of discrete behaviors. While we have limited our discussion to macaques, we believe the Q-sort method can be used for any nonhuman primate species in which infants exhibit persistent attachment behaviors to mothers or others. Reported data were collected in accordance with all applicable animal care regulations, national laws, and ASP Principles of Ethical Treatment of Non Human Primates.

The AQS had been widely used by human attachment researchers for a decade when Kondo-Ikemura, a primatologist, and Waters, a psychologist who had published extensively on attachment theory and co-authored the AQS, adapted the AQS for research with nonhuman primates [Kondo-Ikemura and Waters 1995]. Their initial goal was to create a Q-set that could be used with a wide range of Old World monkey infants. Starting with items that could be adopted from the human infant AQS with only minor revisions (e.g., "leaves infant with a baby sitter" becomes "leaves infant in the care of juveniles or adult females") they wrote thirty-two additional items to capture behaviors that did not have clear analogues in human infant behavior or that referred to situations rarely encountered by human infants. They applied the resulting Q-set (AQS-M) and Criterion Sort in a pilot study of Japanese macaque infants under twelve weeks of age living at the South Texas Primate Observatory in Dilly, Texas.

Infant rhesus macaque attachment research – an illustration of the Q-sort method

In pilot studies for research on infant rhesus macaque attachment patterns at Cayo Santiago, PR, Warfield [2003] found that the AQS-M needed to be modified and expanded to capture the full range of attachment behavior observed in the study's subjects: free-ranging rhesus

macaque infants up to 10 months old living in a naturalistic environment. Kondo-Ikemura had designed the AQS-M for studies of infants under 3 months of age; Warfield's research was designed to span the first 10 months of each subject's life. Items in the new Q-set had to account for the fact that a behavior that would be considered characteristic of attachment security in early infancy could be considered uncharacteristic of attachment security later. For example, playing within 3m of mother before 12 weeks of age might be rated as characteristic of secure attachment, while playing within 3m of mother after 12 weeks might be rated as uncharacteristic of attachment security. In addition, behaviors related to attachment security emerged after 12 weeks that had not been observed in the first 12 weeks. Moreover, at Cayo Santiago monkeys lived within largely intact matrilineal lines in a population where all individuals were identifiable, and their age, rank, and relatives known allowing a fuller Q-set item description of social relationships. While subjects foraged naturally for a large proportion of their caloric intake, they were provisioned in large corrals at water troughs. These research site and age differences required significant modification of the AQS-M. For example, food corrals and water troughs were sites of frequent conflict: whether infants approached these locations with or without their mothers and how they responded to risks in these areas gave rise to several new items.

To convert the AQS-M into the Attachment Q-set for Rhesus Macaques (AQS-RM) the following steps were taken. First, several widely published rhesus macaque infant researchers were consulted to determine whether any rhesus macaque infant behaviors (whether rare or common) related to infant-mother interactions were omitted from the Q-Set, and whether Q-Set items accurately described rhesus macaque infant behaviors. Second, two pilot studies conducted on Cayo Santiago identified additional site-specific behaviors relevant to attachment security. Finally, ethograms in the literature were reviewed to determine if any relevant reported behaviors had not been included. The AQS-RM was then thought to be complete and data collection in the field commenced. However, experience in the field suggested that several items required further modification, especially items for older infants. This final modification was possible because all Q-Sort observations had been videotaped and none had been Q-sorted until after all observations had been completed. This process yielded the final 94-item AQS-RM

(http://www.psychology.sunysb.edu/attachment/measures/content/aqs_rm_items.pdf) which was then used to Q-sort all observations. After all Q-sorts had been completed the AQS-RM Criterion Sort

(http://www.psychology.sunysb.edu/attachment/measures/content/aqs_rm_criterion_sort.pdf) was created by modifying the Kondo-Ikemura and Waters [1995] AQS-M criterion sort. The modification reflected extensive dialogue between Waters, with respect to the meaning of the attachment security construct, and Warfield and others with respect to the behavior patterns of infant rhesus macaques [Warfield 2003].

The AQS-RM was used in a study of 23 infant-mother dyads living on Cayo Santiago [Warfield 2003]. Infants were videotaped for 30 minutes twice every 6 weeks from birth through 42 weeks of age. In addition to these Q-Sort observations, three 15-min continuous focal samples were conducted weekly for each subject from birth through 42 weeks of age by two trained observers recording data on handheld computers using software that had incorporated the project's 196-variable ethogram [Pluim and others 1995]. The ethogram covered infant behavior, maternal behavior, infant-mother interaction, and infant-other interaction. Focal samples were taken at different times than Q-Sort samples to ensure they would be independent. Data were analyzed in seven age blocks: 0–6, 7–12, 13–18, 19–24, 25–30, 31–36, and 37–42 weeks.

Observer agreement and reliability

Intra-observer agreement on criterion sort scores was tested by re-scoring 13 previously scored Q-sorts chosen randomly. Intra-observer agreement was high ($N=13$, $r = .93$, $P < .001$). To evaluate inter-observer reliability, a second Q-sorter trained for approximately five hours observed and provided AQS-RM descriptions of 12 of the same infants. This observer had no previous experience observing primates and had no information about the individual subjects being scored. Inter-rater agreement on AQS-RM security scores was high ($N = 12$, $r = .86$, $P < .01$). These results suggest that highly significant intra-observer and inter-observer Q-Sort score correlations can be achieved; experience with monkey infants or with human infants or the attachment construct does not appear to be required.

Attachment Q-Sort for Rhesus Macaques (AQS-RM): Construct Validity

One of goals of the Cayo Santiago infant study was to assess the construct validity of the AQS-RM using two criteria [Warfield 2003]. First, were AQS-RM scores correlated significantly in the expected direction with discrete quantitative variables traditionally used to measure various elements of infant-mother behavior? Second, were AQS-RM scores stable across ages that made sense developmentally?

Links to behavior sampled using traditional methods

Q-sort scores on attachment security did correlate significantly and in the expected directions with a variety of discrete quantitative variables associated with infant-mother relationships (Table 2). For example, more securely attached infants as measured by the AQS-RM spent less time in contact with their mothers after 3 months of age but not before. More securely attached infants emitted fewer distress vocalizations near their mothers, used their mothers as safe havens when dangerous events put them in harm's way, followed their mothers more often, and received less maternal agonism. At the same time, several variables often thought to be associated with the quality of infant-mother relationships were not correlated with the AQS-RM, including the frequency and duration of nipple contact, maternal grooming, maternal protection, nipple rejection, or maternal carrying (Table 2). The absence of these associations as well as the fact that the significantly correlated variables were not overwhelmingly concordant suggests that the AQS-RM indexes a construct oriented assessment of secure base use in a manner that discrete variable frequencies and durations do not but without losing its grounding in observable behavior.

AQS-RM scores in early and late infancy

Two results from the Cayo Santiago study address whether AQS-RM scores are stable across ages that make sense developmentally. First, mean AQS-RM scores in weeks 0–6 and 7–12 did not differ and were significantly higher than in the subsequent five 6-week age blocks during which they did not differ (Table 3). The decline in Q-scores at three months suggests the interesting possibility that a normative shift occurs in attachment security at three months, an age when rhesus macaques in a semi-natural, provisioned environment are less dependent on their mothers for nutrition, locomotion, and protection [Warfield 2003]. Of course, with an $N=23$ in a single study, these results have to be considered tentative. A second result related to Q-sort score stability within developmental stages is the inter-correlation of AQS-RM scores between weeks 0–6 and 7–12 weeks and 25–30, 31–36, and 37–42 weeks (Table 4). These inter-correlations show that infant security scores were stable through the first 3 months and after 6 months. Although there is only indirect support in the literature for the notion that 3 months and 6 months mark cohesive developmental stages, many studies of nonhuman primate development have used those ages as developmental markers [Berman 1980; Chapais and Gauthier 1993; Hinde and Spencer-Booth 1967; Rosenblum 1968].

None of the above results by themselves demonstrate the validity of the AQS-RM. However, taken together they provide an indication that the efficacy of the AQS in human development research is potentially harnessed by the AQS-RM. Below we briefly present data from some recent preliminary studies that provide additional support for the validity of the AQS-RM and its predecessor while illustrating opportunities for a meaningful expansion of our understanding of the infant-mother relationship and its impacts later in life.

Maternal care, infant attachment security, and later competence

A central hypothesis in human and nonhuman attachment study is that early experience has significant impact on later competence. Developmental psychologists have shown effects of early care on infant attachment security and of infant and childhood attachment to later competence [e.g., Sroufe and others 2005]. Primatologists too have demonstrated links between early care and later competence [e.g., Fairbanks and McGuire 1988]. However, lacking a suitable broad band measure of infant secure base use, primatologists have not tested whether these outcomes are mediated by infant attachment security. The AQS could be instrumental in beginning to address this question.

To confirm attachment security's function as a mediator between independent variables such as maternal care and later outcomes, an association between the independent variable and attachment security must be established [Baron and Kenny 1986]. The results of one recent preliminary study points in that direction. Abusive and control rhesus macaque mothers were observed with their infants to test the hypothesis that abusive maternal care is associated with lower infant attachment security. At 6 months average AQS-RM scores of abused infants were significantly lower than AQS-RM scores of control infants: 0.17 and 0.46, respectively (T-test, $N=20$, $P<.05$) [McCormack and others 2009]. Another finding tentatively linking maternal care and attachment security comes from the Kondo-Ikemura and Waters [1995] study of Japanese macaque infants. They found that many maternal behaviors associated with attachment security in the human literature were significantly correlated with attachment security as measured by the AQS-M and had effect sizes greater than normally reported in the human literature.

A second prerequisite for establishing attachment security as a mediator of later competence is demonstrating an association between attachment security and later competence [Baron and Kenny 1986]. Warfield's 2003 study found tentative evidence of such an association: a significant and large correlation between higher AQS-RM scores of infants of high-ranking mothers in weeks 0–12 and infants' reduced exposure to risk in weeks 13–42 (Spearman rank-order association; $N=10$; $r = 0.76$, $P<.01$). The association did not hold for infants of low-ranking mothers (Spearman rank-order association; $N=13$; $r = -0.11$, ns) suggesting the intriguing possibility that secure base use might mediate risk exposure in infants of high-ranking but not low-ranking mothers.

DISCUSSION

Summary of Key Q-Sort Advantages

Perhaps the most important advantage of the Q-sort method is the ability to score individual differences on conceptually abstract and complex constructs. This affords researchers the opportunity to ask important questions about the role of a complex construct like attachment security, analyzing it as an independent variable, an outcome variable, and as a mediator or moderator variable. The Q-sort method also provides unique benefits in the areas of validity and data collection, scoring, and analysis.

Behaviors observed in appropriate context—With respect to validity, when behaviors are observed in their natural context, measurement validity should be increased. Many behaviors serve more than one behavioral system; for example, an “approach” can be related to hunger, aggression, sexuality, or secure base use. Generally, traditional sampling methods code only the actor and target of an “approach.” Validity increases when the meaning of a behavior is clarified through its contextualization, as it is with the AQS.

Appreciating the significance of infrequent behaviors—Validity can also be increased when rare or infrequent behaviors can be accounted for meaningfully. Traditional quantitative ethological methods assign little weight to rare or infrequent behaviors: when several subjects do not exhibit a given behavior and their “cells are empty” statistical analysis of that behavior is problematic. Q-sets incorporate such items, and even if the items do not occur during a large number of observations, they can have a measurable affect on scores when they do occur.

Data collection and scoring—The Q-Sort method often requires far fewer samples than traditional quantitative sampling [Warfield 2003], an important time-saver for free-ranging subjects where finding the subject can be more time-consuming than conducting and scoring the observation. When it comes to scoring, halo effects and biases can be minimized by keeping observers blind to the constructs they are scoring. Retest effects can be avoided because the AQS assesses behavior as and where it occurs whether subjects are captive or free-ranging so subjects are not put through repetitive protocols or experimental paradigms.

Data analysis—Since a Q-Sort score is a continuous variable, it can be correlated readily with other continuous variables and used more effectively in regression. Continuous variables lend themselves to a wide range of data analytic strategies using general purpose statistical software. The criterion sort procedure permits researchers to develop criterion sorts and assign scores on new variables long after data collection has been completed. This is a great advantage in longitudinal research. Interpreting unexpected results or alternative hypotheses is often facilitated by the ability to score subjects on a variable for which no specific measure was included in the original study.

Summary of Key Q-Sort Disadvantages

The principal disadvantage of the Q-Sort method may be its requirement to create the Q-set and to explicitly define the construct of interest in terms of the Q-set items. Of course, this depends on the construct in question. The criterion sort is really a hypothesis about how each descriptive item is related to the construct. Therefore, it may be desirable to reach out to experts beyond the research team which could add time and complexity to the research.

A second disadvantage could be the need to collect quantitative data as well as conducting the Q-sort observations. If the research hypothesis requires the construct to be related to quantitative variables, there would have to be independent observations of subjects, adding cost.

CONCLUSION

It has been 25 years since Waters and Deane [1985] first used the Q-sort method to develop the Attachment Q-sort (AQS) that operationalized the Bowlby-Ainsworth conceptualization of attachment behavior: the use of a secure base from which to explore and as a haven of safety. The AQS allowed quantitative comparison and analysis of individual differences in attachment security in naturalistic studies of attachment behavior. The AQS has now been used in scores of published studies on maternal care and infant security, stability and change

in infant behavior, and links between early experience and later competence. This paper is the first detailed exposition of the Q-sort method addressed specifically to primatologists and comparative psychologists. We hope that by detailing the method and illustrating some of its uses and advantages for research with nonhuman primates the bridges between two important traditions in attachment study will begin to be rebuilt and nonhuman primate studies will once again inform attachment theory. In addition, we believe that use of the AQS can extend and enrich our knowledge of nonhuman primate societies including social organization and relationships, sex and rank differences, emigration patterns, and other issues that continue to intrigue nonhuman primate researchers.

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REFERENCES

- Ainsworth, MDS.; Blehar, M.; Waters, E.; Wall, S. Patterns of attachment: A psychological study of the strange situation. Hillsdale, NJ: Erlbaum; 1978.
- Andrews MW, Rosenblum LA. Attachment in monkey infants raised in variable- and low-demand environments. *Child Development*. 1991; 62:686–693. [PubMed: 1935339]
- Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*. 1986; 51:1173–1182. [PubMed: 3806354]
- Berman CM. Early agonistic experience and rank acquisition among free-ranging infant rhesus monkeys. *International Journal of Primatology*. 1980; 1:153–170.
- Block, J. The Q-Sort Method in Personality Assessment and Psychiatric Research. Harrower, M., editor. Springfield: Charles C Thomas - Publisher; 1961. 161 p.
- Bowlby J. The nature of the child's tie to his mother. *International Journal of Psychoanalysis*. 1958; 39:1–24. [PubMed: 13513206]
- Bowlby, J. Attachment and Loss: Volume I. Attachment. New York: Basic Books; 1969/1982.
- Bowlby, J. A Secure Base. New York: Basic Books Publishers, Inc.; 1988.
- Cassidy, J.; Shaver, PR., editors. Handbook of attachment: Theory, research, and clinical applications. NY: Guilford Press; 1999. 925 p.xvii
- Chapais, B.; Gauthier, C. Early Agonistic Experience and the Onset of Matrilineal Rank Acquisition in Japanese Macaques. In: Pereira, ME.; Fairbanks, LA., editors. Juvenile Primates: Life History, Development, and Behavior. New York: Oxford University Press; 1993. p. 245-285.
- DeMulder EK, Denham S, Schmidt M, Mitchell J. Q-sort assessment of attachment security during the preschool years: Links from home to school. *Developmental Psychology*. 2000; 36(2):274–282. [PubMed: 10749084]
- Fairbanks LA, McGuire MT. Long-term effects of early mothering behavior on responsiveness to the environment in vervet monkeys. *Developmental Psychobiology*. 1988; 21(7):711–724. [PubMed: 3234602]
- Hinde RA, Spencer-Booth Y. The behaviour of socially living rhesus monkeys in their first two and a half years. *Animal Behaviour*. 1967; 15:169–196. [PubMed: 4961894]
- Kondo-Ikemura, K.; Waters, E. Maternal behavior and infant security in old world monkeys: conceptual issues and a methodological bridge between human and nonhuman primate research. In: Waters, E.; Vaughn, BE.; Posada, G.; Kondo-Kimura, K., editors. Caregiving, Cultural, and Cognitive Perspectives on Secure-Base Behavior and Working Models: New Growing Points of Attachment Theory and Research. Serial No. 244. Nos. 2–3 ed. Vol. Vol. 60. Chicago: The University of Chicago Press; 1995. p. 97-110.

- McCartney K, Owen MT, Booth CL, Clarke-Stewart A, Vandel DL. Testing a maternal attachment model of behavior problems in early childhood. *Journal of Child Psychology & Psychiatry*. 2004; 45(4):765–778. [PubMed: 15056308]
- McCormack K, Warfield J, Dozier M, Gunnar M, Maestripieri D, Waters E, Sanchez MM. Measuring Attachment Security In Captive Rhesus Macaques (*Macaca Mulatta*). *American Journal of Primatology*. 2009; 71 Supplement:63.
- Pluim, R.; Jansen, H.; Wammes, A. User's Manual. Version 3.0. Wageningen: Noldus Information Technology; 1995. The Observer, Support Package for the Psion Workabout.
- Rosenblum, LA. Mother-infant relations and early behavioral development in the squirrel monkey. In: Rosenblum, LA.; Cooper, RW., editors. *The Squirrel Monkey*. New York: Academic Press; 1968. p. 207-233.
- Schino G, Troisi A. Relationship with mother modulates the response of yearling Japanese macaques (*Macaca fuscata*) to the birth of a sibling. *Journal of Comparative Psychology*. 2001; 115(4):392–396. [PubMed: 11824902]
- Sroufe, LA.; Egeland, B.; Carlson, E.; Collins, WA. *The development of the person: The Minnesota longitudinal study of risk and adaptation from birth to adulthood*. New York: Guilford; 2005.
- Sroufe LA, Waters E. Attachment as an organizational construct. *Child Development*. 1977; 48:1184–1199.
- Stevenson-Hinde J, Stillwell-Barnes R, Zunz M. Subjective assessment of rhesus monkeys over four successive years. *Primates*. 1980; 21:66–88.
- Suomi, SJ. Influence of attachment theory on ethological studies of biobehavioral development in nonhuman primates. In: Goldberg, S.; Muir, R.; Kerr, J., editors. *Attachment Theory: Social, Developmental, and Clinical Perspectives*. Hillsdale, NJ: The Analytic Press; 1995. p. 185-201.
- van IJzendoorn MH, Verijken CMJL, Bakermans-Kranenburg MJ, Riksen-Walraven JM. Assessing Attachment Security With the Attachment *Q* Sort: Meta-Analytic Evidence for the Validity of Observer AQS. *Child Development*. 2004; 75(4):1188–1213. [PubMed: 15260872]
- Warfield, JJ. Doctoral Dissertation. New York: Columbia University; 2003. Attachment Bonds And Behavior In Free-Ranging Male Infant Rhesus Monkeys: Species-Typical Patterns And Individual Differences In Secure Base Use And Security; 600 p.
- Waters, E.; Deane, KE. Defining and assessing individual differences in attachment relationships: Q-methodology and the organization of behavior in infancy and early childhood. In: Bretherton, I.; Waters, E., editors. *Growing points of attachment theory and research*. Chicago: The University of Chicago Press; 1985. p. 41-65.
- Waters, E.; Vaughn, BE.; Posada, G.; Kondo-Ikemura, K., editors. *Caregiving, Cultural, and Cognitive Perspectives on Secure-Base Behavior and Working Models: New Growing Points of Attachment Theory and Research*. Chicago: The University of Chicago Press; 1995.
- Weaver A, de Waal FBM. An Index of Relationship Quality Based on Attachment Theory. *Journal of Comparative Psychology*. 2002; 116(1):93–106. [PubMed: 11930937]

Figure 1. Schematic diagram of stepwise procedure for arraying 90 Q-set items into nine piles. (From Vaughn & Waters, in press).

Table 1

Data Format for Q-Sort Descriptions of a Target Individual

	Observer 1	Observer 2	Observer Average
Item 1	4	1	2.5
Item 2	8	6	7.0
Item 3	7	5	6.0
Item 4	3	2	2.5
.			
.			
Item n			

Note: Scores in the first two columns are based on the piles into which the items were sorted. Right-most column is the composite (i.e., averaged) Q-sort description of the target individual.

Table 2

Association Between Attachment Security Indexed by AQS-RM Scores at 13–42 weeks and Infant or Infant-Mother Behaviors

Behavior Pattern	AQS-RM Scores
Contact Index (13–42 wks)	-.39 [^]
Distress vocalization: % of obs.	-.44 [*]
Distress vocalizations: rate on mother.	-.35 [^]
Distress vocalizations: rate in arm's length	-.37 [^]
Distress vocalization: rate .6m – 3m.	-.47 [*]
Following mother: ratio of follows to mother leaves.	.46 [*]
Going to mother following most serious risk events: percent of events	.53 ^{**}
Going to mother following serious risk events: percent of events	.44 [*]
Maternal agonism: (13–42 wks)	-.43 [*]
Carried by Mother: % of observations, (0–12 wks)	-.10
Carried by Mother: % of observations, (13–42 wks)	.14
Grooming by mother: total duration	.08
Grooming by mother: mn bout	.14
Nipple contact: % of observations, (0–12 wks)	-.02
Nipple contact: % of observations, (13–42 wks)	-.08
Nipple contact: mn bout duration, (0–12 wks)	.00
Nipple contact: mn bout duration, (13–42 wks)	-.08
Nipple rejection: % of attempts to gain nipple, (0–12 wks)	-.09
Nipple rejection: % of attempts to gain nipple, (13–42 wks)	-.23

Notes: N = 23. Pearson correlations (2-tailed): [^] = < .10, ^{*} = < .05, ^{**} = < .01.

Table 3

AQS-RM Scores Across 6-wk Age Blocks: Mean $\pm$ SE

Age	0-6	7-12	13-18	19-24	25-30	31-36	37-42
Mean	.47a	.44a	.26b	.29b	.26b	.29b	.26b
Score	$\pm .02$	$\pm .03$	$\pm .03$	$\pm .03$	$\pm .04$	$\pm .03$	$\pm .04$

Note: N = 23. Letter indicates whether mean is significantly different at .05 level after Bonferroni adjustment for pairwise comparisons (Repeated Measures ANOVA).

Table 4

Correlations among 6wk AQS-RM scores

Age Block	0-6	7-12	13-18	19-24	25-30	31-36
0-6						
7-12	.53*					
13-18	-.07	.19				
19-24	.19	.31	.08			
25-30	.03	-.02	-.05	-.21		
31-36	-.08	.01	-.21	-.41^	.49*	
37-42	.28	.27	-.09	-.22	.55***	.80***

Notes: N=23. Pearson product-moment correlations: ^p < .10; *p < .05; **p < .01; ***p < .001.