I usually begin by describing what we have found in our basic laboratory research using animal models, how these give us a new understanding of attachment, and finally, when there’s no time left, I get around to mentioning the implications for clinical intervention. In this paper I’m going to begin with the implications, and then tell you about the research that led us to them. I hope that this format will encourage discussion and elicit ideas from you. I think that what I am proposing will fit well with the conclusions coming from attachment researchers working with people and in very different settings. This is as it should be and is reassuring for the future of translation between basic and clinical studies in this area.

The first implication is a relatively broad one, and it concerns the kinds of behaviors and interactions that we try to modify in our interventions. Evidence over the past two decades, from field studies in primates (Kraemer, 1992) and experimental studies in laboratory animals like rats (Polan and Hofer 1996), has convinced most of us that attachment is not a unitary system. It’s a concept like appetite, which is composed of a number of different underlying processes such as the development of motor and sensory systems, perception, attention, learning, memory, motivation, and affect, as well as the more complex kinds of experiences focused on in this volume. And together they generate the phenomena we describe as the attachment system, as well as generating other broad areas of functioning. The implication of this is that the focus of intervention, ideally, should be at the level of these constituent processes because these are what make the attachment system work.

Let me give you an example from our research. Only very recently we think we discovered the learning process that underlies the infant’s development of the ability to know its own mother and to want to stay close to her. This is the imprinting-like process that Bowlby (1982) hypothesized as
a mechanism of bond formation in humans. And this comes from the work
of Regina Sullivan (summarized in Hofer and Sullivan 2001), who did her
dissertation work in our lab and is now at the University of Oklahoma.
She discovered a particular kind of learning, found only in the newborn
and early infant rats, in which they learn to discriminate and prefer to stay
close to a particular test odor as a result of one conditioning experience in
which the odor was associated with gentle stroking, warmth, or milk. As a
result, what happens next is that the pup now prefers that odor, seeks it
out, and stays near it. When this is the mother’s odor, this is the mechani-
ism of the bond. Two things are unique about this: the learning is very
rapid—only one or maybe two 15-minute exposures create memories last-
ing many days. Secondly, the kinds of associated experiences that create
these memories for the mother’s odor include not only gentle stroking and
warmth, but also painful stimuli such as a tail pinch and even mild electric
shock—at least during a critical period in early development that lasts for
only the first 8–9 days after birth, equivalent to the same number of months
for the human infant. After that age the pup becomes more sensible and it
 learns to avoid an odor previously associated with painful stimulation. But
if the pain-odor association begins in the first week, and is repeated daily,
the pup will continue to show attachment to the odor for many days.

If this novel kind of learning is also seen in human infants, it gives us a
new way to understand strong attachments we see in abused infants. When
I told my wife, Lynne, a psychoanalyst and a grandmother, about this amaz-
ing finding, she replied, “How could you be surprised?” We now have to
figure out how to intervene in this novel form of learning, or should we
simply be quicker to recommend foster care for abused infants?

The second implication I see is that interventions need to occur very early
in infancy—in fact, during fetal life. We have known for some time that
specific human maternal cues are learned before birth—voice (Fifer and
Moon 1995) and probably smell. This form of learning has been now ex-
tensively studied in fetal rats and some of its properties are well known. In
some recent work that Jon Polan and I (Polan and Hofer 1999a) conducted
with newborn rats, we found that they learn very early to respond with
vigorous attachment behaviors to a range of maternal cues in the first few
nursing bouts. These are graded, sensory-guided behaviors, not simply re-
flexes as Bowlby assumed. And they are graded in the sense that they are
more intense, the more specific the mother-like features (e.g., cotton, fur)
with which the pup is presented. Within a day or two after birth, the pup
have developed a responsive motivational system and will increase the level
of these attachment behaviors as a result of a period of deprivation. In short,
we have found that the full behavioral attachment system develops in the
infant much earlier than Bowlby thought and in a more primitive animal
than anyone had thought possible 20 years ago. These results strongly sup-
port efforts to design interventions that begin and even focus on the fetus
and perinatal period. For it is now apparent that the groundwork for all
later attachment patterns is likely to be formed in the first days of the in-
teractions between human infants and their mothers, if not even in the fetus
period.

In human mothers we know that a particular form of the mental working
model discussed in this volume can be traced back to the mother’s own
experiences as an infant. Most of us have thought that this is a uniquely
human phenomenon, even a cultural phenomenon. But Michael Meaney and
his colleagues at McGill (Francis, Diorio, Liu, and Meaney 1999) have es-

tablished that specific characteristics of maternal behavior are passed from
generation to generation, even in rats, based on the interaction patterns that
the mother rat had in her own infancy. The implication here is that this
simple behavioral transgenerational mechanism may be operating in humans
where it may act as a biological foundation on which the complex mental
representations that are studied in human infant attachment are formed.

This brings us to the third area, the question of how changes in at-
tachment patterns can be brought about by interventions. The answer to
this question is going to come out of knowing more exactly how the par-
tent–infant interaction shapes development. This is the “transmission gap,”
in our understanding. Here our discovery of hidden regulators may be of
help. As you may know, we have found that many of the changes that
occur in infant rats separated from their mothers are due to the withdraw-
or loss of individual regulatory effects of specific components of the pre-
vious mother–infant interaction, such as touch or warmth or smell (Hofer
1995). So the infant’s complex physiological and behavioral responses to
separation, these multiple kinds of responses involving a variety of organ
systems and behaviors, are the result of the release from these different
regulators that occur at the time of separation from the mother, some-
what like the withdrawal from drugs or alcohol. And because the regula-
tory interactions are hidden within the ongoing mother–infant relation-
ship, and because they appear to act throughout early development, they provide a new way to understand just how different patterns of ongoing mother–infant interactions shape or regulate the course of development over time.

Taking this idea of hidden regulators together with the need for earlier intervention, the implication is that we should focus our interventions on very simple stimuli with premature infants and babies. Here warmth, rhythms of touch, smell, oral stimulation, and so forth are as effective in inducing attachment and regulating development as more complex interactions will be for older infants, and the more complex interactions may require the formation of a firm base of these simpler mechanisms.

But should we be directing so much attention to interventions with the infant? Should we be paying more attention to the mother instead? Animal model studies generally have had more success working with the maternal side of the interaction in order to induce long-term effects in the infants. Even when the intervention is directed at the infant, the long-term effects on later infant development are sometimes mediated through the mother, much to the surprise of the experimenter. For example, in a recent study (Huot et al. in press), infant rats were separated from their mother for three hours every day. As adults, these rats were found to be more fearful and have a greater adrenocortical response than if normally reared. But if the dam was provided with foster pups during the 3-hour periods in which her pups were separated from her, the long-term effects on the infant disappeared! Apparently these repeated 3-hour separations were not what affected the infant’s development. It was the effects of the separations on the mother, changing her behavioral interactions with her infants over the other 21 hours of the day, that altered long-term infant development.

In addition, individual characteristics of the infant animal can have powerful effects on maternal interactions, and change long-term outcomes. And here’s where temperament and more subtle individual differences in newborn human characteristics (see Belsky, this issue) become so important to take into account. Thus the intervention of foster mothering in the laboratory does not always work— for the behavior of the foster mother changes with the infant being fostered. It even makes you wonder whether the best way to change the human mother’s behavior is going to be through her infant.

**Summary**
Recent research on the developmental processes underlying early attachment behavior is beginning to answer several major unanswered questions of attachment theory: How does the infant come to recognize his mother, seek her out, and stay close to her? How does separation from the mother create such widespread effects on the infant? And how are specific patterns of mother–infant interactions transmitted across generations?

The answers that are emerging have three important implications for intervention: One, continue to expand the focus of intervention efforts into a broader range of the infants’ cognitive and emotional processes, and with more emphasis on interactions with the mother that fall outside the traditional categories of attachment behavior. I think we’ve seen examples of that in this volume, including the facial mirroring described by Beatrice Beebe.

Two, look for ways to intervene earlier in development and experiment with interactions that involve multiple sensory systems of the newborn using simple biological interventions involving touch, warmth, smell, oral stimulation, and the senses of position and motion of limbs and the body in space. For example, see Morris Eagle’s discussion of the baby carrier effect (pp. 19-20, this volume).

Three, increase focus on the maternal side of the interaction. The mother’s environment outside of her relationship with the infant should be explored as an area for intervention. In the mother–infant interaction, think of new ways to alter how the infant influences the mother instead of concentrating on how the mother influences the infant. Finally, above all, question your preconceptions, try out new things, and think broadly of the mother and infant developing together, rather than limiting your thinking to the boundaries of our current model of attachment.

**References**


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**WHY THE “TRANSMISSION GAP” IN ATTACHMENT RESEARCH: DIFFERENTIAL SUSCEPTIBILITY TO REARING INFLUENCE?**

Jay Belsky, Ph.D.

A major challenge to students of attachment theory is what van IJzendoorn (1993) has referred to as the “transmission gap”—the gap between what can and cannot be explained about the determinants of attachment security in infancy. Theory suggests that the most important determinants of attachment security should be the sensitivity with which mother cares for the child, yet the predictive power of measured sensitivity appears to be modest (de Wolfe and van IJzendoorn 1997), even though experimental research clearly demonstrates that sensitivity causally contributes to the development of attachment security (van den Boom 1994, van IJzendoorn et al. 1993). Relatedly, while mothers’ own state of mind with respect to attachment, as measured by the adult attachment interview, has proven to be rather strong (van IJzendoorn 1995), the presumed mediating mechanism—namely, maternal sensitivity—has not. So again we are confronted with the reality that our power to predict attachment security via maternal sensitivity is nowhere near what we would expect on the basis of theory. Why is that?

Three possible—and nonmutually exclusive—explanations to this conundrum are considered in this chapter. First I will consider what might be labeled “the measurement gap,” that is, that limitations of measurement may result in underestimates of the effects of sensitivity on attachment security. Next I will consider the possibility that insufficient attention has been paid by students of attachment theory to what might be regarded, from the mother’s perspective, as “time on task,” and from the infants as the sheer

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