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COMMENTARY

Advancing and Integrating the Cusp Concept to Understand Behavioral Repertoire Dynamics

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Abstract

The behavioral repertoire grows and develops through a lifetime in a manner intricately dependent on bidirectional connections between its current form and the shaping environment. Behavior analysis has discovered many of the key relationships that occur between repertoire elements that govern this constant metamorphosis, including the behavioral cusp: an event that triggers contact with new behavioral contingencies. The current literature already suggests possible integration of the behavioral cusp and related concepts into a wider understanding of behavioural development and cumulative learning. Here we share an attempted step in that progression: an approach to an in-depth characterization of the features and connections underlying cusp variety. We sketch this approach on the basis of differential involvement of contingency terms; the relevance to the cusp of environmental context, accompanying repertoire, or response properties; the connections of particular cusps to other behavioral principles, processes, or concepts; the involvement of co-evolving social repertoires undergoing mutual influence; and the ability of cusps to direct the repertoire either toward desired contingencies or away from a growth-stifling repertoire. We discuss the implications of the schema for expanded applied considerations, the programming of unique cusps, and the need for incorporating cultural context into the cusp. We hope that this schema could be a starting point, subject to empirical refinement, leading to an expanded understanding of repertoire interconnectivity and ontogenetic evolution.

Keywords cusp · behavioral cusp · behavioral development

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Perhaps because of the power and significance of the concept, the behavioral cusp has seen an accelerating influence in behavior analysis in conceptual, theoretical, and empirical work (Becker et al., 2021). Rosales-Ruiz and Baer (1996) originally defined the behavioral cusp as "an interaction, or complex of interactions, that enables access to new reinforcers, new contingencies, and new communities of reinforcement and contingencies—and thus to new behaviors" (p. 165). As a nonlinear concept, the cusp describes causal connections across rather than within individual contingencies: connections that can have disproportionate impact on the subsequent repertoire. This impact on the repertoire can be conceptualized as history effects, but in addition to the universal sense of "historical" (i.e., working through time and resting on the order of events [Tatham & Wanchisen, 1998]), the cusp specifies a way in which previous contingencies have an effect on the control exerted by subsequent contingencies (Freeman & Lattal, 1992). The cusp and similar between-contingency connections can help account for changes in the behavioral repertoire over time that work cumulatively.

The cusp is an important component of a behavioral approach to development. In contrast to approaches involving stage theories of development or restricted descriptions of normative sequences (i.e., developmental milestones; Piaget, 1964), a behavioral approach to development identifies causal connections between events within a sequence, and the variables that can change them. For this reason, the behavioral approach to development handles an impressive breadth of phenomena, including trajectories that operate not only in typical development but also in idiosyncratic and atypical development (Rosales-Ruiz & Baer, 1996). The cusp is related and complementary to other nonlinear behavior analytic concepts, which have already been somewhat integrated in general behavioral developmental work (e.g., Bijou, 1993; Bosch and Hixson, 2004; Hixson, 2004; Hixson et al., 2011; Jiménez et al., 2022; Novak & Pelaez, 2004; Reese, 1982; Schlinger, 1995).

In the present article, we hope to add to existing work in the cusp literature by putting forward a characterization of cusps relative to several other related phenomena in behavior analysis, which together may contribute to holistic understanding of the evolution of a behavioral repertoire—programmed or unprogrammed—through time. We wish to suggest a paradigm that can be used to characterize cusps and draw connections between cusps and related concepts, which are often related but not interchangeable. In so doing, we hope to complement existing conceptual research that seeks to refine the concept of behavioral cusps. We also discuss a few potential directions for future investigation illuminated by our suggested framework and the important outcomes that such work may produce. We hope that this article will increase and inspire empirical scrutiny to address the underdevelopment of the topic in proportion to its potential. We feel that the time is ripe for widespread empirically guided advancement in this subfield, particularly because the acceleration in the current cusp literature consists primarily of interpretive application rather than theoretical testing, refinement, or advancement, with notable exceptions (Becker et al., 2021).

The Behavioral Cusp: Current Conceptualizations

Behavioral cusps are most often conceptualized as response forms to be trained. For example, some of the most commonly described cusps include walking, naming, and reading (Hixson, 2004; Rosales-Ruiz & Baer, 1997). In addition to simple response forms, Hixson (2004) identifies common cusps consisting of complex, higher-order operants or multibehavior skills such as generalized imitation, relational responding, and problem solving as well as cusps that are defined by properties of a response such as fluency and generalization. He also includes the conditioning of social stimuli as reinforcers as a common cusp, which is neither a response form or a response property but rather a conditioned stimulus function (also see Maffei et al., 2014). Play and social skills are also a common set of cusps that likely incorporate many of these complexities (Charlop et al., 2018). The original definition of the cusp as "an interaction, or complex of interactions, that enables access to new reinforcers, new contingencies, and new communities of reinforcement and contingencies-and thus to new behaviors" (Rosales-Ruiz & Baer, 1996, p. 165) technically could also include instances of "an interaction" induced by an environmental shift that enables new reinforcement contingencies even without any new learning. For example, the infusion of new people into a community may enable new reinforcement contingencies for long-time residents. The definition of a cusp thus includes an incredible variety of phenomena, yet still distinguishes cusp events from noncusp events in a functional way. Even a common response form such as reading (Rosales-Ruiz & Baer, 1997) would not be a cusp unless it led to contact with a future contingency, which it may not do if the person lives in a country that uses a different alphabet than the one they learned, and therefore never encounter the new contingencies that reading may otherwise lead to in other contexts. Thus, although almost any learned response or environmental shift could potentially be a cusp if conditions are right, almost none are guaranteed to be a cusp.

The variety of currently accepted cusps suggests that conceptual distinctions between different kinds of cusps are not only possible but could help in the processes of identifying or programming them. Such an exercise may also lead to awareness of new potentials based on any gaps suggested by the conceptualization. In the remainder of this article, we will build one potential paradigm for cusp conceptualization for that purpose.

Qualities of Typical Cusps

Although particular response forms frequently function as behavioral cusps across people, it is important to remember that no particular response form guarantees contact with future contingencies. Despite this fact and despite the fact that the cusp definition isn't strictly limited to a learned response, cusp research gravitates toward common potential cusp response forms and functions, such as those listed above (e.g., reading, walking, imitation; Hixson, 2004). Although practical considerations might lead to this tendency, the confirmation that a cusp has occurred

must technically occur posttraining rather than pretraining when identifying learning targets. Yet because the contact with new contingencies that the cusp enables may not occur until well after cusp training is complete, the training of a purported cusp cannot be an endpoint, either. For example, learning to code may be a cusp for an individual who later encounters new job-related contingencies as a result, but the job in question may occur years after the skill has been acquired. We can fully identify a cusp only after it has actualized, and we can demark a noncusp only once the organism runs out of future environments. Likewise, the identification of reinforcers also requires empirical testing and confirmation, but cusp identification carries another complication because the cusp function is usually a unique point in a behavioral development sequence, unlikely to be repeated in similar form again for the same individual. Cusp functions can therefore be predicted only by guessing that they will be repeated across organisms, leading to identification of "typical" cusps within developmental contexts (Hixson, 2004; Hixson et al., 2011). The tendency for cusps and other developmental regularities to occur across many individuals also gives them a role in population-level, cultural, and evolutionary processes as well as individual learning (Ariew, 1996; Glenn et al., 2016; Jablonka, 2007; Jiménez et al., 2022; Malott, 2016; Waddington, 1942). These facts imply that for intervention and applied research, evidence of efficacy requires follow-up confirmation of cusp function, which is not presently common.

Even though most currently popular cusps are either assumed or targeted to occur across most individuals, a cusp need not be present for more than one person in order to be a cusp. For example, visual thinking in general (Patten, 1973) together with a well-practiced thought experiment about looking at oneself in a mirror while traveling at the speed of light (Banerji, 2006) led Albert Einstein to generate the special theory of relativity, which unlocked many future contingencies and proved to be an entirely unique cusp of some importance. Even when not totally unique, cusps may be rare and highly contextual; skills such as political savvy, technical expertise, survival skills, physical prowess, etc. may prepare individuals for unique arrays of future contingencies relevant to only a subset or even a minority of individuals. Thus, the challenge of engineering unique or rare cusps requires consideration of how to predict a cusp function without many other organisms with which to compare and how to approach the contextual requirements surrounding the cusp that may not be universal. Developing techniques to do so would enable a new level of individualized behavioral programming. A more in-depth characterization of the varieties of cusp features across known cusps may aid in this effort.

In-depth Characterization of Cusps: Initial Considerations

At a minimum, explicit training of a cusp requires the involvement of two contingencies: the contingency establishing the cusp itself (hereinafter, "cusp contingency") and at least one other future contingency that the cusp enables (hereinafter, "new contingency"). These contingencies exist in a wider environmental and stimulus

context. We will refer to these as either the cusp contingency context or the new contingency context.

The terms of the respective contingencies (antecedent, A; behavior, B; and consequence, C) in classic examples are not equally vital to establishing the cusp. In the classic reading cusp for example, the textual nature of the response form is more critical than the consequence that initially trains it. It may be possible therefore to characterize cusps based on the contingency elements that are critical for realizing it. We will refer to the elements of the contingencies as the A, B, and C terms of the cusp contingency (the original training) or the new contingency (the contingency enabled by the cusp).

Some cusps may also require more than two cusp contingencies (as in when both driving and reading are required for future use of road maps), or may require particular conditions surrounding the contingencies (as in when access to certain textual stimuli is required for reading to be a cusp). In addition, some cusps may occur via other processes identified in behavior analysis (e.g., shaping, recombination). To refer to the entire set of behaviors, conditions, contexts, and processes necessary to render a cusp—both in the training environment and the future environment in which contingencies are encountered—we will use the term "cusp complex."

We will build an initial characterization that draws distinctions among cusp variations based on (1) what term(s) of the cusp contingency and of the new contingency (i.e., antecedent [A]; behavior [B]; consequence [C]) are affected or enabled for a given cusp, (2) whether the cusp behavior itself is currently sufficient for the new contingency to take hold or whether some other unestablished histories or conditions (i.e., other relevant conditions) are also required for the cusp to function, and (3) whether another principle, process, or concept moderates the impact of the cusp or constitutes its mechanism.[1]

The Role of Contingency Terms

A cusp may operate by (1) altering the availability, efficacy, or nature of antecedent conditions in a new contingency; (2) providing a repertoire of response forms sufficient to meet a new contingency; (3) establishing the function of a consequential event in a new contingency; or (4) a combination thereof.

Cusps that Provide the Antecedent (the A term) for New Contingencies The first case (altering the availability, efficacy, or nature of antecedent conditions) includes possibly the most classic example of the cusp concept: a response that provides physical access to a new antecedent environment (e.g., walking, driving; Rosales-Ruiz & Baer, 1997). For example, learning to drive provides access to contingencies in locations where the individual has never visited. Such a cusp doesn't generally operate via the B term of the new contingency because at least the initial approximation of behavior must already be in the repertoire. The focus on the A term in these

[1] To avoid confusion relating to the multiple uses of the term "mechanism," we clarify that we mean simply a description of the physical way in which an abstract phenomenon is brought about.

kinds of cusps may not be absolute; it can be argued that the new environment may contain the new consequence as well (e.g., arriving at a grocery store where food can be obtained), but the sensitivity to the consequence as a reinforcer in such examples does not necessarily depend on acquisition of the cusp response itself. Thus, this type of cusp may be classified as working primarily through the new antecedent environment and indirectly through access (though not usually sensitivity) to the consequence of the new contingency.

Cusps that Provide the Behavior (the B term) for New Contingencies The cusp contingency may function via the behavior (the B term of the ABC contingency, defined either topographically or functionally) of the new contingency by setting up critical components, capabilities, prerequisites, or initial approximations necessary for meeting a new contingency (e.g., reading, phonetics, simple abstractional discriminations; Johnson et al., 2021). These cusp topographies may, once acquired, satisfy a new contingency and perhaps be further shaped by it (note here that the new contingency has a B term (behavior) but not a C term (consequence) in common with the cusp contingency). Such a cusp necessarily occurs via contingency adduction as it was defined by Andronis et al. (1997)[2]: "[contingency adduction occurs when] repertoires established in one contingency context later met the formal requirements of entirely new contingencies, and thereafter comprised a wholly different functional class of behavior" (p. 15). In other words, the same event qualifies as adduction (because a response form that was learned under one consequence has fulfilled another consequence) and as a cusp (because the response form led to contact with a new contingency).

Again, it may be argued that the cusp rarely depends purely on the B term. The A term may also hold some importance for generalization of the behavior to the new environment, though many or most properties of the new antecedent environment (A term) may differ markedly from the original (e.g., textual stimuli must be present both when acquiring phonetic skills and when reading a menu to order dinner, though likely in a different configuration). Especially if one conceptualizes the A–B relation as the unit modified by selection (i.e., the stimulus control topography; Ray, 1969), then B-dependent cusps must also at least initially depend on some property of the cusp A, and the varieties of ways in which that may occur could further refine the characterization.

Cusps that Provide the Consequence(s) (C term) for New Contingencies Finally, some purported cusps seem to be functioning by conditioning stimuli that can then

[2] Note that here we are using the term "adduction" in the sense originally cited by Andronis et al. (1997), and that later, Catania (2004) described the term differently: "The coming together of existing responses in novel combinations to produce new behavior is sometimes called adduction" (p. 55). In Catania's definition, a new consequence is not required at all; instead, two initial responses are either combined or sequentially emitted in a manner controlled by antecedents (a phenomenon frequently occurring in verbal behavior). We are using the term recombination rather than adduction for the phenomenon described by Catania (2004). It may be that both processes could occur at once, with two responses combining and thereby satisfying a new contingency not responsible for the original development of either component response. We refer to this case as "recombinant contingency adduction."

act as consequences (the C term) in future contingencies. For example, the acquisition of conditioned social reinforcers serve as critical cusps for the development of socially mediated repertoires (Hixson, 2004). We would usually conceptualize the original cusp contingency in such a case as respondent, although it can be considered in the operant framework too under the theory that conditioned reinforcement occurs when the reinforcer acquires a particular discriminative stimulus function (da Silva & Williams, 2020; Holth et al., 2009; Kelleher & Gollub, 1962; Vandbakk et al., 2019). Under the operant paradigm, this means that the antecedent (A term) of the cusp contingency (e.g., the smile that has been trained as a reinforcer because it signals that the child may successfully reach for preferred objects and edibles; Isaksen & Holth, 2009; Olaff & Holth 2020) has established the consequence (C term) of the new contingency (Vandbakk et al., 2019).

Although the three-term contingency constitutes a good starting point for this kind of analysis, the extension of the concept to contingencies involving greater numbers of terms may be possible. For example, the fourth term in conditional discriminations may operate to enable a cusp similarly to a single A term. If conditional discriminations (e.g., Schrier & Thompson, 1980), equivalence class formation (e.g., Sidman, 2000), or higher-order operants (e.g., Catania, 2006) including relational frames (e.g., Barnes-Holmes and Barnes-Holmes, 2000) establish a new future function for class members, then that term could form an avenue to a cusp function. The combinatorial potential for such arrangements prohibits a thorough description of all possible configurations, but the potential for *n*-term cusp functions greatly expands the potential variety of cusp complexes. The red section of Fig. 1 visually describes our suggested conceptualization of the ABC-based characterization of a cusp's function.

Relevant Conditions

With these term-based distinctions in place, we may now further characterize the varieties of cusps by identifying other possibly relevant conditions that may be necessary, in particular cusp cases.[3] We suggest that a cusp can be characterized based on whether or not each of these conditions are necessary for the cusp function to occur. Hypothetical examples are listed below (for cited examples, see the subsequent discussions).

1. **The coexistence of other responses in the repertoire**. For example, question-asking or information searching may only function as a cusp after an individual also learns discrimination of reliable sources, approach behavior, autoclitics related to politeness, or library/computer skills. The difference between this necessary, prerequisite repertoire and the cusp itself could be a (perhaps accidental) matter of sequence; a final prerequisite may function as a cusp simply because it was learned last.

[3] We intend this list as a launching point and do not strive for exhaustivity.

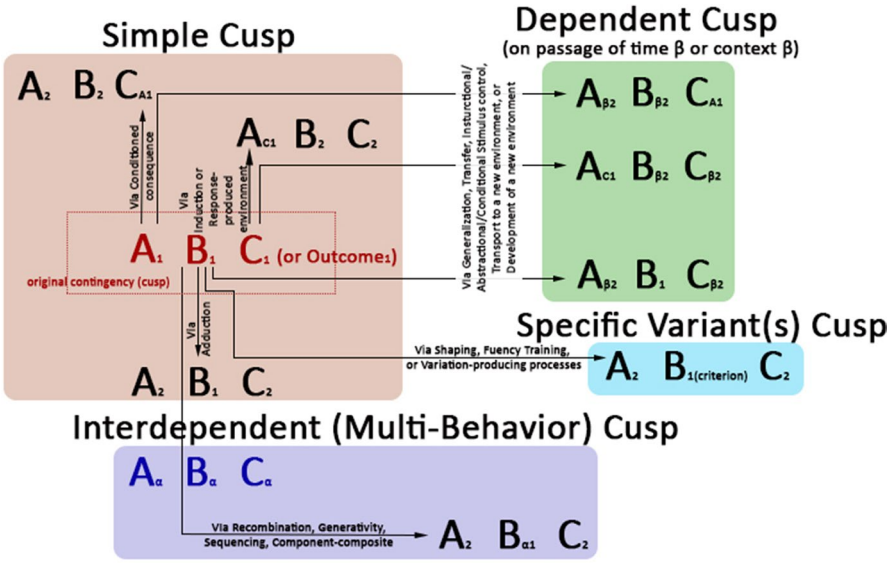

Fig. 1 Visualization of Simple, Dependent, Specific Variant Cusps, and Interdependent Cusps

2. **The passage of time or a new environment**. For example, fluent spatial reasoning skills learned in childhood may function as a cusp years later when a person uses that spatial reasoning to contact contingencies in a new professional environment as a designer or architect. We deal separately with the social aspect of new environments given the involvement of social variables changes the reach and implications of this point—see condition 6 below.
3. **The stimulus control, generalization, or transfer of cusp responses or other responses**. For example, time management or organizational skills acquired in a high school setting may need not only to be in the repertoire but also may need to be explicitly occasioned or transferred to a novel, less structured higher education or professional context in order to be a cusp.
4. **The fluency of the cusp response or related responses. A particular response may become a cusp only when some portion of it reaches a certain dimensional requirement**. For example, verbal skills trained only to a level sufficient for interaction with a well-known family member, friend, or therapist—or to a level only sufficient for relatively inefficient, difficult conversation—may later reach a level of fluency that enables further-reaching verbal exchange with a wider variety of individuals (e.g., community members, strangers).
5. **Response variability**. Future contingencies may involve somewhat unpredictable criteria that may not overlap at all with those of the original cusp contingency. In these cases, response variability in the original cusp may be necessary in order to contact the new contingencies. For example, someone may learn to play an instrument mainly via contingencies presented by a music teacher. Perhaps only if the response variability established through the course of this training is sufficient, the person may eventually improvise musical patterns that meet new contingen-

cies—perhaps widely varied from any that the teacher directly reinforced—that connect to new consequences in other audiences. Variability may often be necessary for cusps working via contingency adduction (via an original B term).

6. **Initial, ongoing, or interactively directed repertoires of other individuals in the environment**. Receiving environments containing social contingencies (see #2 above) may be required for a socially mediated cusp. Unlike in purely nonsocial environments, the reciprocity of social environments expands the potential forms that such cusps may take. For example, cusp behaviors such as providing social reinforcement (e.g., saying "thank you" or otherwise reinforcing engagement, prompting conversation or cooperation) could actually teach people in the social environment to interact more often, thereby creating previously nonexistent social contingencies. In that case, the cusp helps to create (rather than simply contact) new contingencies in the social environment. Such a cusp may also rest on preconditions in the repertoire of social partners: prior conditioning that prepares them to appropriately learn from the cusp behavior. For example, telling the truth under difficult circumstances (when lies hold advantages) may function as a trust-building cusp that unmasks social contingencies in a relationship, but perhaps only with partners that have a discriminative history with lies in context. Such cusps may also operate in socially undesirable ways as when the cusp constitutes con artistry. Reciprocally iterative dynamics in socially mediated behavior potentially amplifies the effects of associated cusps via co-evolution of repertoires (Fig. 2). Such cusps could operate via many more degrees of freedom than nonsocially mediated cusps, suggesting a greater complexity and reach.

The list of fundamental characterizations above may occur in combinations. For example, cusps that involve social conditions may also work via controlling antecedent contexts, enabling an "ecological cusp" as described by Binnendyk and Lucyshyn (2009). In their feeding study, Binnendyk and Lucyshyn (2009) trained not only target behavior, but also a contextual routine in which that contingency was situated: the snack routine. Although this was a case study and not a single-subject experimental study, they observed several nonlinear benefits that appeared after their training, including acceptance of new, untrained foods and more positive behavior—particularly in the stimulus context of the routine. The authors speculated about the reasons for these nonlinear benefits, including a change in the caregivers' behavior in the training context, who may have begun to encourage development of further independent behaviors—even behaviors unrelated to the original cusp (Binnendyk & Lucyshyn, 2009). Note that the suggested function here depends on cusp-induced variation and stimulus control of the mediating behavior of other people rather than of the cusp behavior itself. This differs from the child's acquisition of an overall learning set or learn-to-learn repertoire (which could be conceptualized as a group of cusps operating mostly via multiple responses, generalization, and recombination) because the latter operates by changing the child's behavior with respect to learning environments rather than changing the environment itself (i.e. the contingencies available in the social environment). The ecological cusp implies that a newly acquired behavior may trigger new contingencies by reinforcing caregivers for, in turn, providing unspecified reinforcement contingencies more readily in a

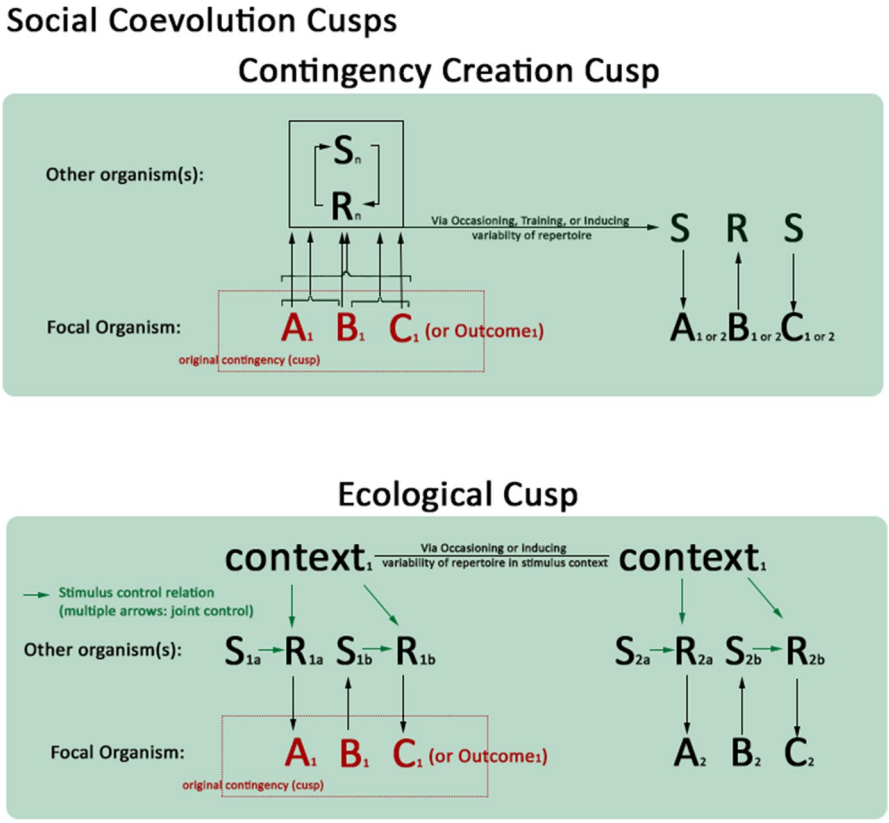

Fig. 2 Visualization of Cusps Requiring Socially Co-evolving Contingencies

particular context. If this speculation passes empirical scrutiny, it implies that indirect, multivariate "cusp complexes" can function in a manner twice removed from the original cusp contingency.

The Involvement of Other Principles, Processes, or Concepts

The discussion thus far has already prompted us to foreshadow our third focus in characterizing particular cusps: the involvement of associated behavior analytic concepts such as adduction, recombination, and generalization (e.g., Epstein et al., 1984; Goldstein & Mousetis, 1989; Kirby & Bickel, 1988; Lee et al., 2007; Shahan & Chase, 2002; Stokes & Baer, 1977). We will next explicitly consider what additional concepts may be likewise important. To do this, we focus on (1) concepts that involve or may involve multiple contingencies; and (2) concepts that operate via history effects. These include component–composite relationships (e.g., Newsome et al., 2021), scope and sequence (e.g., Spencer, 2021), generativity (Slocum & Rolf,

2021), consequence conditioning (e.g., conditioned reinforcement; Cló & Dounavi, 2020), resurgence (e.g., Podlesnik et al., 2022), derived relations (e.g., Doughty and Best, 2017) and other history effects (e.g., Okouchi & Lattal, 2006; Salzinger, 1996). Alike with the cusp concept, these concepts often describe relations that occur only once within the individual lifetime, (though they are often repeated across individuals), and that either can't be demarcated or aren't particularly useful to demarcate until after the fact. For example, component behaviors aren't so named unless the composite behavior is also eventually trained, and conditioned consequences must function after they are conditioned to be so classified.

Because some of these other historical concepts overlap with and co-occur with the cusp, they may become confused with it. For example, acquisition of a component behavior such as arithmetic may create a newly realizable reinforcement contingency for a composite such as financial planning and may count as both a component and a cusp. Likewise, generativity describes the fulfillment of a new contingency via recombination of previously established behavior (Andronis et al., 1997), such as when an animal can solve a novel problem (e.g., how to obtain food that is out of reach) by combining previously learned behaviors (e.g., moving objects and climbing onto them; Epstein et al., 1984; Epstein, 1999). If the generative episode involves a new consequence/contingency, the array of recombined behaviors could arguably each count as a cusp. As they stand, we consider these related concepts not as redundant but rather as separable descriptors that combine and interact. A single physical event may involve more than one of the concepts, which can be approached as distinct properties of the event rather than independent parts of it. For example, analysis of a cusp that operates via recombination calls for specifying points of contact between the two concepts rather than blending them (Williams, 2021; Jiménez et al., 2022). The cusp function remains in the relationship between the acquired behavior and contact with a new contingency, and the recombination function in the relationship between component responses and combined response. Neither function is strictly necessary for the other to occur: the recombination may proceed in exactly the same way with no future contingencies, or the future contingency may arise via a different mechanism of response acquisition (e.g., direct shaping). For example, an organism may solve the problem of how to obtain food that is hanging from the ceiling (a new contingency) by recombining previously learned responses involving moving objects around and climbing on them (i.e., an instance of both recombination and cusp; Epstein et al., 1984). The same cusp may also be realized by directly teaching the chain as a whole without recombining any previously learned responses (i.e., cusp but not recombination). As an alternative, an animal trained to push objects around may occasionally jump on them if climbing was already in the repertoire, even if no subsequent contingency is thereby connected (i.e., recombination but not cusp).

Taken together, the characterization of cusps based on (1) the contingency terms that connect the cusp contingency with new contingencies; (2) relevant conditions necessary for cusp function; and (3) involvement of other principles, processes, or concepts can be combined to provide a characterization of any given cusp that describes the full cusp complex. Such a characterization could help identify necessary and unnecessary conditions for programming an overwhelming variety of

cusps. Figures 1 and 2 synthesize these concepts visually into our initial suggested schema. The "simple cusp" (pink) in Fig. 1 shows basic cusps using each of the three terms and notes potentially connected component processes. The first item from our list of relevant conditions—cusps that also require other responses in the repertoire—are depicted at the bottom of Fig. 1 (blue). We refer to these as "interdependent cusps." The second through fifth from our list of relevant conditions—dependent on the passage of time, the receiving environments/contexts different from the training and/or environment, the transfer or generalization of stimulus control, are depicted on the right side of Fig. 1 (green) and named "dependent cusps." Cusps that rely on fluency or variation in behavior are shown in teal and called "specific variant cusps." These various kinds of cusps are labeled with commonly co-occurring processes that can act as mechanisms for the cusps including recombination, generativity, sequencing, and component-composite learning. Figure 2 abstracts the final item from our list of relevant conditions for cusps that operate via changes in the repertoire of others (i.e., ecological cusps; Binnendyk & Lucyshyn, 2009).

This initial model poses new questions because the arrangement we've suggested makes certain gaps salient. We've included the modification of all the terms of a new contingency and all of the old, but not all combinations. Other avenues of cusp function may thus potentially await discovery. Relations between consequences ("C" terms) of both contingencies seems particularly underexplored; such relations may be important and may have already been inductively suggested in the study of choice paradigms, differential outcomes, and economic substitutes; much of this work has not been squarely posed in terms of specifically historical questions, and none in terms of cusps. To illustrate a hypothetical example of how economic substitutes might be related to a cusp, we will use the example of electricity. People involved with businesses that sell electricity have wide experience with sourcing materials such as coal to generate it. From early periods through present day, the provision of coal as a consequence for a variety of cusp behaviors for people in the energy industry led to a positive feedback loop: reinvestment and growth in the energy infrastructure tailored to electricity including jobs, electric grids, and propagation of products that run on electricity. This positive feedback loop potentiates the provision of economic substitutes for individuals in the energy infrastructure (e.g., gas, solar generation equipment, or land for wind farms) when coal is restricted or unavailable. Under the right conditions, the potentiation of these substitutes could lead individuals with previous repertoires maintained by coal provision (cusp contingencies) to contact new contingencies and develop new expertise consequated with provision of alternative energy sources (new contingencies).

This model also leaves room for incorporation of other nonlinear or history-based principles that may at times be related to cusp function including but not limited to resurgence (Epstein, 2015; Hull, 1934, 1952; Podlesnik et al., 2022; Shahan & Craig, 2017), alternative sets (which describe contingency interactions; Goldiamond, 1975), behavioral momentum (Nevin, 2015), errorless learning (Poolton et al., 2005; Sidman, 2010; Terrace, 1963; Touchette & Howard, 1984), and blocking (Kamin, 1968; Rescorla, 1988; Vandbakk et al., 2020).

Elaborations and Additions to the Paradigm

The initial characterization that we suggest can be expanded to include some elaborations: those already suggested by the literature and those that may come from new analysis or empirical insights. We now discuss a few of these.

Undesired Cusps and "Impedance Cusps"

Rosales-Ruiz and Baer (1997) acknowledged that some cusps may be unwanted: for example the introduction of an addiction. In addition, behaviors likely to interfere with an individual's learning in a school context (e.g., hitting, spitting) can also be conceptualized as undesired, or negative behavioral cusps (Robertson, 2015). For example, if a child hits a peer (a behavior initially reinforced by the peer's reaction) it may provide access to attention-related contingencies when the caregiver or teacher reprimands the child (e.g., "We don't hit our friends") as well as access to new environments with potentially new contingencies (e.g., sitting in the hallway or detention). Peers in such scenarios often also either provide attention or distance themselves from the individual engaging in such behavior, changing the social environment into one even more likely to reinforce even more antisocial behavior. Although such behavior might be labeled as "maladaptive," "problematic," or "destructive," it still provides a means to access new reinforcers (Carr & Durand, 1985). A cusp that leads to contingencies deemed to be "undesirable" cannot be distinguished in terms of process from a cusp that leads to desired contingencies.

Our suggested paradigm might incorporate undesired cusps by indicating how they would operate and thereby suggesting mechanisms by which they could be prevented or inhibited. The inhibition of an undesired cusp itself may even count as another kind of cusp if it redirects a behavioral trajectory toward a different set of more desirable contingencies, or a more desired behavioral trap. For example, Rosales-Ruiz and Baer (1996, 1997) pointed out that teaching a child too readily to ask for help (Rodriguez et al., 2017) rather than attempting to solve the problem independently (Frampton and Shillingsburg, 2018; Skinner, 1953) prevents contact with contingencies for problem-solving skills; preventing this prompt-dependency under key conditions may therefore count as a cusp by preventing a block to contingency contact. This literature suggests that some cusps may work in this way—by preventing behavior rather than by permitting it—at least in the short term (e.g., Luna et al., 2022). Wherever otherwise likely behavior may interfere with the progression of a cusp, we should include the inhibition of that behavior at least as a necessary condition in the cusp complex if not as the core cusp itself. For any such cusp that operates via inhibition of a cusp-inhibitor, we suggest the term "impedance cusp."

Such a scenario may roll out in one of two ways: (1) the cusp response directly outcompetes an existing, cusp-blocking response; or (2) the cusp response entirely prevents contact with contingencies by which a cusp-blocking response might be learned (Fig. 3). For example, mands can replace "inappropriate" behavior

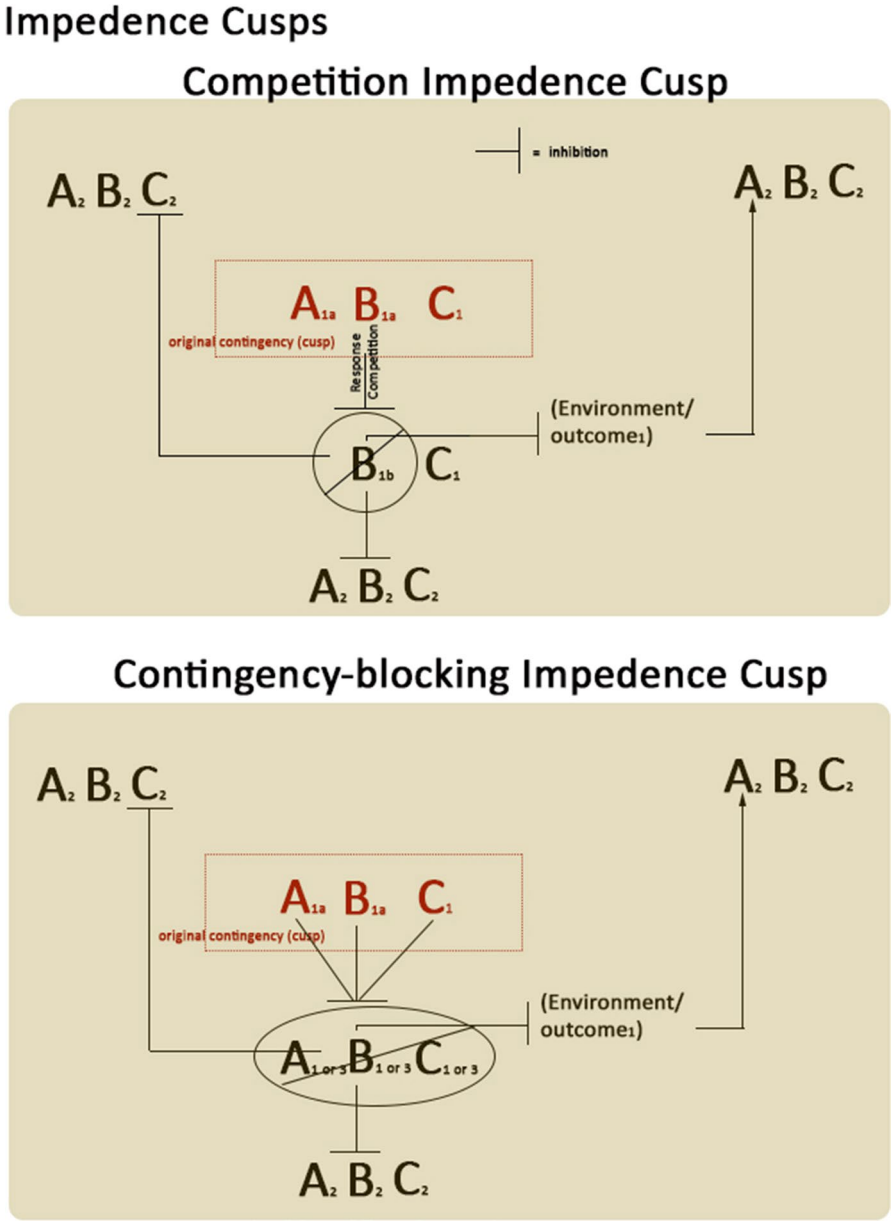

Fig. 3 Visualization of Impedance Cusps

previously maintained by access to items or attention (Bosch & Fuqua, 2001), which may lead to contact with social contingencies previously blocked by the interfering behavior: the first kind of impedance cusp. In support of this idea, differential treatment effects when implementing functional communication training (Carr &

Durand, 1985) have been found depending on a learner's initial manding repertoire (Ringdahl et al., 2009; Torelli et al., 2016). It follows that should such a response be learned before any interfering response has occurred, it could block the development of the "problem" behavior in the first place: the second kind of impedance cusp. Similar proactive work has already been suggested (e.g., Ala'i-Rosales et al., 2019; St. Peter & Marstellar, 2017).

Unlike the classic cusp, the impedance cusp works by constraining some contingencies in order to provide contact with others. We do not suggest here the impossible task of considering all potentially interfering behavior. The identifiability of such a cusp should arise from observations of other known cases (similar to identification of other common cusps (e.g., Hixson, 2004), or from reasonable predictions based on the individual's history (a provider familiar with a client's repertoire and reinforcers may accurately anticipate cusp-incompatible behaviors that are likely to develop; Ala'i-Rosales et al., 2019). Contingency constraint may be difficult to differentiate from contingency unavailability and may require reference to a known and relevant scope and sequence. In the case of impedance cusps involving widespread problems among humans, similarities between individual developmental sequences are likely common, and using control groups in a longitudinal approach such as that of Staats (1977) could allow observation of "what might have happened."

Punishment Cusps

Unwanted cusps and impedance cusps help to illustrate the potential importance of adding constraint on the repertoire and/or environment in order to direct behavioral growth into key learning trajectories. Of course, other known behavior-constraining contingency frames may also work well in our paradigm. It may be possible that a punishment function may also serve this purpose, particularly when punishment prevents the development of interfering behavior in a manner similar to impedance cusps. Of course, punishment does not produce a specific B term, though it may indirectly produce nonspecific Bs via negative reinforcement. If the topography of the alternative, negatively reinforced behavior is the critical feature leading to future contingencies, the cusp is probably better conceptualized as an impedance cusp that depends on (negative) reinforcement. If instead it is only important that topographical alternates NOT take a particular form (the punished form) in order to unlock future contingencies (i.e., antisocial or rude behavior), then the focus on the punishment rather than negative reinforcement frame as a cusp may be more appropriate. We propose that a consideration of the potential for "punishment cusps" may lead to interesting basic questions as well as critical targets for various kinds of intervention.

Before we describe this thought process further, we would like to qualify that we do not suggest any support for the use of contrived punishment. We do not believe that the application of contrived punishment can ever be ethical unless all conceivable alternatives (including doing nothing) would impose even greater harm—and even then, unless great care is taken to minimize the scope and intensity

of the punishment and its associated effects to the lowest effective level. That said, the topic still bears practical importance given typical development almost always involves automatic, noncontrived aversive functions (Critchfield, 2014) and even positive interventions may indirectly operate in relation to aversive processes (Perone, 2003).

When expressed in a healthy context, low-intensity, nonrestrictive[4] punishment contingencies may help to protect an individual from harm and direct a developmental trajectory toward physical well-being, social actualization, and skillful productivity. As an example, consider the relationship between minor physical pain and well-being. The nociceptive sensation of pain is almost always a primary punisher, and contrived delivery of pain has been a horrific theme of human history. Yet at low intensities, good behavioral health depends on automatic nocioception, and individuals born without it are vulnerable. Because they do not learn to shift away from positions that subtly damage their body and do not feel immediate punishment as a consequence of putting themselves at high risk for both major and minor injury, they tend to experience progressive physical deterioration and early death (Losa et al., 1989; Nagasako et al., 2003). Likewise, minor and nonrestrictive conditioned punishment and social punishment may help to direct healthy behavior and may play an important part in the enabling of greater sophistication of cooperative and prosocial behavior. For example, if body language indicating discomfort in others is conditioned as a minor punisher (i.e., the development of empathy for pain), the social repertoire will be shaped to exclude the subset that is aversive to others, provided that social reinforcers can be earned in a variety of other ways. This could serve not only ethical and practical interests of interacting communities as a whole, but may even help to optimize performance with respect to the positive contingency and/or cumulatively unlock relationship-related future contingencies for the individual—a punishment cusp.

In these examples, the potential for punishment sensitivity to act as a cusp is limited to contexts of plentiful alternative responses for positive contingencies; outside of such a context, punishment may (1) eliminate entire response classes rather than refining them, preventing the development of desired topographies necessary to contact future contingencies; (2) directly compete with positive contingencies, rendering the efficacy of the punisher inversely proportional to deprivation for the positive consequence; and (3) most likely induce or intensify harmful side effects, including generalized avoidance of cusp-critical environments, approach-avoidance patterns, negative emotions, generalized negative emotions, trauma, etc. In addition to plentiful alternatives, prevention of side effects may also depend on a low intensity of the punishment and ease of the avoidance (i.e., fluency of alternatives). For example, feeling minor stiffness and pain isn't really a problem when we are allowed to easily avoid them by shifting our weight, seeking comfortable or supportive chairs and beds, stretching, etc. Acute or unavoidable pain operates differently; sitting in a chair could be rendered traumatic if shifting and stretching are blocked. Likewise,

[4] We use "nonrestrictive" to indicate ready alternative access to the positive consequences that support the punished response. In other words, the individual's repertoire supports alternate ways to easily obtain relevant positive consequences other than via the punished behavior.

successful avoidance of signs of discomfort/censure in an audience by shifting or varying autoclitic frames may not result in negative side effects, but if the censure is intense, unavoidable, unpredictable, or noncontingent it may occasion negative emotional responses, avoidance of the environment, or antisocial countercontrol. Again, we suggest that this kind of cusp must critically refer to the punishment contingency itself rather than the alternative (negative reinforcement) contingencies if the critical property of the cusp is the form of the eliminated behaviors rather than the form of their alternatives. Figure 4 visualizes such punishment cusps.

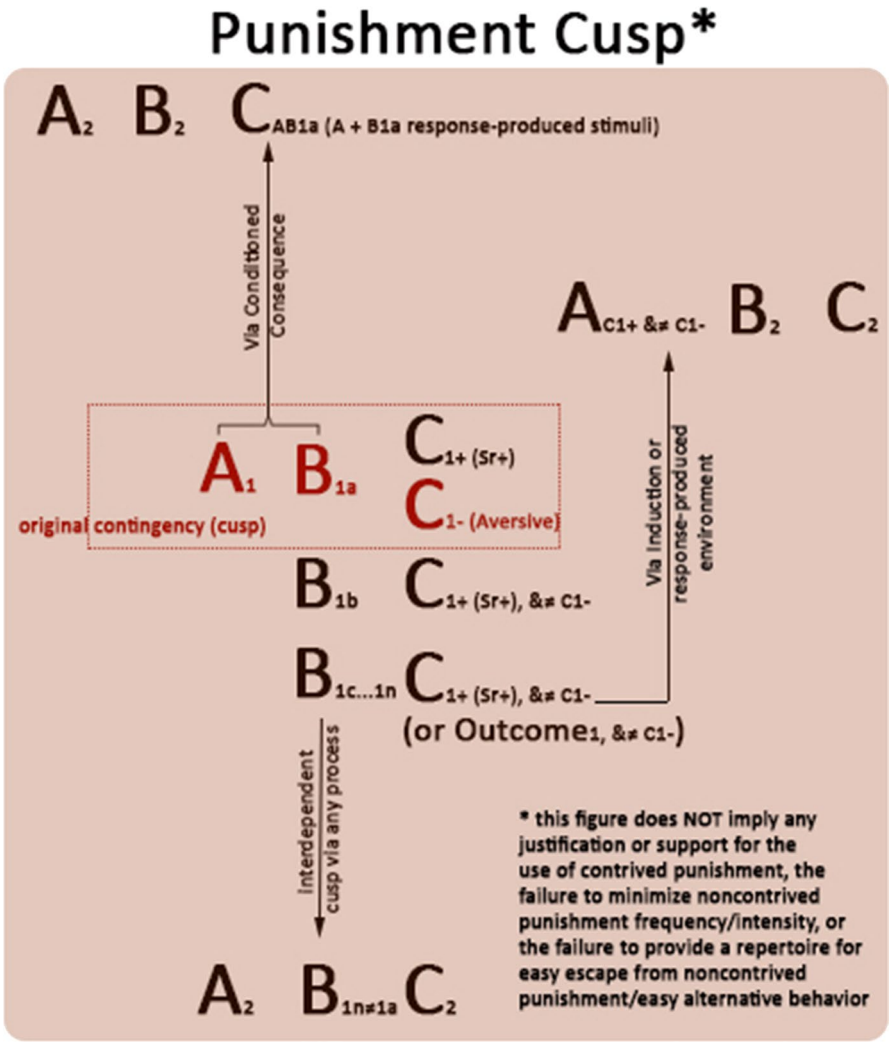

Fig. 4 Visualization of Punishment Cusps

Implications and Reflections

Expanded Considerations When Programming for Cusps

These complexities may appear irrelevant to many applications of cusp technology. Identifying and training common cusps at least sometimes requires no additional characterization, and the tools already developed in the field such as criteria for a priori selection of target behaviors (as described by Bosch & Fuqua, 2001) already serve well in the practical conceptualization of cusps. Behaviors such as phonemic awareness, generalized imitation, etc. are likely to function as cusps in a wide range of human environments and thus don't seem to require a characterization of a "cusp complex." However, they still require that complex to be in place. In the case of reading, for example, the cusp complex may include access to reading materials relevant to future contingencies, search skills, social skills, vocabulary look-up skills, discrimination skills about the reliability of information sources, or a largely literate community (Stokes & Baer, 1977). Simple cusp interventions rest on the dependability of at least some of these complexities rather than their absence, so the ability to refer to them when needed could still advantage an intervention.

Our characterization draws sharp focus onto a wide array of programmable aspects of cusps. This refocus emphasizes that training certain response forms in an individual isn't the only way to create a cusp; for example simply transporting a person into an environment that can connect to their current repertoire in cuspable ways may constitute a cusp intervention. Building such an environment around the person could also create a cusp, as for example has been the case in the reshaping of public spaces and signage to increase accessibility or the development of new and accessible online learning resources (Twyman, 2011). Social initiatives have often served to change or introduce cusp environments for women, minorities, or other marginalized groups (Iwarsson & Ståhl, 2003). Changing communities can be a form of mass intervention, too; the propagation of prosocial, accepting, helping, or teaching behaviors can transform a community environment into one that produces unplanned cusp functions in more individuals more often. Many behavioral needs might be met in the most potent and widespread way by adjusting the accepted social contingencies to meet common repertoires instead of changing the repertoire of each individual to meet a preexisting yet arbitrary norm.

Estimation of Important Variables Even for Rare Cusps

We've asserted that simple cusps rest on the ubiquity of a cusp complex, and programming of an environment may create new ubiquities. Yet a cusp can also occur without any ubiquity, and in such cases they may still hold great importance for the individual. These kinds of cusps may be relevant to certain professions, aspirations, and challenges that individuals are facing. Of course, skilled teachers, mentors, and consultants probably already address these needs to some degree and almost certainly create cusp complexes even for rare cusps, often without systematic analysis

and perhaps without awareness. Yet even those examples grounded in behavior analysis aren't always explicitly aiming for a holistic identification of the cusp complex, and doing so (or doing so more often) may provide a useful tool. For example, Direct Instruction (DI; Engelmann & Carnine, 1982) is complex, multicomponent instructional program that focuses on efficient instruction of component skills to fluency via frequent reinforcement (Barbash, 2012). Although not explicitly stated, DI harnesses the power of cusps to teach reading. Other examples include instructional design (Gilbert, 1976; Markle, 1990; Tieman & Markle, 1991) and instructional programs (Engelmann & Carnine, 1982; Johnson & Layng, 1994; Johnson & Street, 2020; Leon et al., 2011; Twyman et al., 2004). An explicit approach would incorporate much of what already occurs in these subfields, but with increased and more explicit focus on building custom cusp complexes that may include multiresponse components for recombination (e.g., complementary or component skills; Andronis et al., 1997; Frampton et al., 2016), response elements around the cusp itself including targeted generalization/transfer (e.g., appropriate stimulus control and generalization; Schilmoeller & Etzel, 1977; Stokes & Baer, 1977), skills that enable physical exposure or entry to the key future environment, skills that enable entry into requisite social environments (e.g., behavioral traps or "a community of reinforcement contingencies which will shape and maintain an ever-increasing repertoire of social behavior and will put that behavior under the control of peers"; Baer & Wolf, 1967, p. 15, as cited by Jiménez et al., 2022), fluency tailored to contact a variable array of natural contingencies, or response variability to ensure that the most effective response form will be available in or refined by unspecified future environments, etc. (Jiménez et al., 2022). It is critical to note that the approach would also seek not only to identify and program, but also to confirm target cusp functions and their dependence on the other concepts already utilized in these practices. In this way, our suggested paradigm may both inform and be informed.

Culturally Responsive Cusps

The cusp function critically depends on an environment containing new contingencies, as we and prior authors (e.g., Rosales-Ruiz & Baer, 1996, 1997) have already suggested. That environment is often physically and always socially constructed in a manner informed by cultural variables. Thus, cultural variables determine both the status and the reach of a cusp response. The refocus that we suggest from a single-variable cusp to the entire cusp complex encourages a consideration of the culturally specific elements of cusp complexes in context. As the discipline strives to meet the need for culturally-responsive service provision (e.g., Fong et al., 2016), this refocus could prove useful. For example, effective social skills may be cusps in any community, but in some communities the requisite contingencies may involve different topographies of conversation initiation, gaze direction, or pausing. Of course, the environmental consistencies created by cultural regularities might pose many questions at other levels of selection as well. A cusp-like concept has even been suggested on the level of human systems and culture to account for far-reaching effects of cultural developments (Glenn et al., 2016; Jiménez et al., 2022; Malott, 2016).

Application of the Approach to Basic and Translational Investigation

Although the applied literature has created a firm foundation for the development of cusp concepts, basic literature on the topic remains circumscribed. A review of the literature on behavioral cusps (Becker et al., 2021) produced only one article published in the *Journal of the Experimental Analysis of Behavior* (JEAB) that referenced cusps: a nonexperimental article reviewing behavior analytic terminology (Tuomisto & Parkkinen, 2012). This finding suggests that there is little or no basic behavior analytic research directly on behavioral cusps (although as we mentioned, work on related concepts may implicitly also experiment with cusps). The fact that the implications of cusps and other developmental behavioral principles are highly content-determined may be one reason why applied scientists have so predominantly taken up the mantle. Still, basic research remains critical for growth in any science (Kyonka & Subramaniam, 2018), and content-related questions about the workings of cusps may still be investigated in the lab. Some work in the laboratory has been pivotal as proof of concept for cusp-related topics within our schema: for example, experiments on generativity (Epstein et al., 1984; Epstein, 1999). Basic work can explore questions that may be unethical or difficult to address first in application. We feel therefore that a great unrealized potential remains for the study of cusps and other developmental phenomena in the basic laboratory. We hope that the proposed schema here may frame the cusp in an abstract, process-based manner that facilitates its basic investigation. Patterns of contingency connections should be amenable to content-independent interrogation in the basic laboratory, opening avenues for translational work in behavioral development.

A Starting Point for New Research and Development of Theory

Our suggested characterization holds promise only insofar as it could lead to successful experimentation, novelty, and increased applied efficacy (Stokes, 1997). Behavior analysis already describes complex learning scenarios profitably; these concepts will be useful only if unifying the somewhat fragmented current concepts into a holistic characterization can drive experimentation and discovery of new potentials, adding power, intention, and analysis to the already powerful practices currently in place. Here, we have begun to sketch connections between historical and cross-contingency concepts in a cusp-centric way, but the approach we have taken could be expanded to integrate more completely with related concepts to produce a truly behavioral, individually flexible, and parsimonious theory of lifetime development united in a larger, abstracted model that incorporates connections between elements of the repertoire and identifies the possibilities forthcoming from their configurations. For example, a schema like the one we have suggested provides a relative frame that might be iterated forward or backward through time, shifting the operant(s) of central focus, with surrounding content also naturally shifting through progressive swaths of the repertoire through time. Even though no particular cusp will repeat ontologically, the pattern of relationships between contingencies might, and if so the conceptualizations like the one we have suggested could help to make

those patterns clearer. The ability to zoom in or out of the cumulative and exponentially growing systems of connections between repertoire elements and to incorporate many behavioral principles or concepts within individually unique frames could help to investigate processes of cumulative hierarchical learning (Hixson, 2004; Staats et al., 1970). The selection-based causation to which behavior is subject easily incorporates into this conceptualization as well. At each branch, selective retention among the current variation can be indicated via the contingencies themselves, and the mechanisms described at each point could make clear where processes are constrained or enabled by the spatiotemporal connections between contingencies and between variants, enabling the visualization of the behavioral developmental landscape (Juarrero, 1999; Waddington, 1942, 1957).

Summary and Conclusion

In summary, we have used current thought on the cusp concept, various examples from the literature, and our own elaborations to create a unified paradigm that permits characterization of cusps via the "cusp complex." We base this paradigm on the terms through which original and future contingencies are related, through the various other conditions that may be necessary for the complex to function as a cusp, and through the relationship between the cusp function and other processes or concepts operative in a particular case. Although retaining parsimony and generality, our approach can enable precise interrogation of particular cases by focusing on the nature of unique intercontingency connections. It might also be useful for the basic interrogation of intercontingency arrangements in the laboratory and for facilitating cultural sensitivity of cusp programming. We hope that this exercise can help the field to identify research gaps, test current assumptions and understanding, further characterize a general theory of behavioral development and nonlinear dynamics, and engineer highly complex individual instances of ontologically unique cusp events. Increased scrutiny, refinement, and focus into various elements of this unifying scheme (or a better, alternative one) may prove disproportionately powerful for the future of the science and the technology: a potential cusp ready for assembly.

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