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Research Article

Cognitive Dynamics of Emotion to Motion: A Framework for Human Robot Interaction

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Abstract: Emotion and motion triggered by emotion plays a vital role in human robot interactive communication and emotion triggered by Motion or action is vice-versa. Cognition of motion and emotion defines the interactive behaviour of human, and it is important perspective for human robot interaction. The cognition of motion and emotion, and interactions based on such cognition also result a cyclic process as well as generation of new experienced based memory which defines future course of interactions. A basic emotion model for robot and its possible implementation and a method to evaluate intuitive sense of feeling associated with motion using robot as a tool are past proposed work by author. In this paper author trying to extend both the aspect to propose the possibility of human robot interaction based on emotion and motion as a series of episode in daily life environment.

Keywords Cognitive Dynamics, Emotion for Robot, Motion Planning, Human Robot Interaction, Emotion to Motion

Introduction

Well organized learned motion and action is performed through real-time decision action process. For example, action to grab a coffee is walk to the table to get coffee cup. The musculoskeletal and nervous system provide an autonomy based on motor learning for repeated motion (Marieb and Hoehn, 2012). This is a kind of feedback system to achieve target motion trajectory with time scaling whenever required. This decision to grab coffee is based on certain state of feeling/emotion, in this case like feeling thirsty (Tripathi et al., 2013). This feeling drives to search for coffee in environment and make a move/action to get it. However, there may arise a feeling of discomfort in while performing well trained motion in daily life. Which may create a state of emotion as annoying, discomfort and pain, for example there is sudden ankle twist when standing to grab coffee due to environment condition (Smith, 2020). This feeling of discomfort is subjective and its evaluation involve consideration of human-robot interaction. A framework of emotion model supposed to provide structure in the form of internal state (Tripathi, 2019). Further, an intuitive sense of real time decision can be represented based on this internal state of emotion and real time interaction with environment (Tripathi et al., 2015).

The autonomy of musculoskeletal motion is based on learning of repeated motion on fast time scale. However, there is global monitoring with slow time scale precise motion and action, which involves decision based on internal state of emotion and feeling too. Central nervous system works as this global monitoring system. This possibility occurs when there is mismatch between well learned motion/action and real time performance and feeling discomfort arises (Tripathi et al., 2013). This is possible with an 'awareness' state that makes conclusion what and why, based the real-time interaction and events occurring in environment (Ramachandran and Blakeslee, 1998; Cicerone et al, 2005). The event occurring as an action in environment and a real-time assessment is termed as action-perception cycle (Van, 2009; Wagatsuma and Tomonaga, 2011). The perception cycle considers observation with awareness to afferent input from environment as well as internal state. This aware state decides the action course and efferent output to motor action is generated.

Figure 1 shows a basic cognitive connection between episodic memory, event, object and emotion triggered by that, as well as event and action due to an emotion state. As the perception cycle involves internal state of feeling of discomfort and emotion state, human robot interaction based on emotion to motion concept needs an emotion model to represent different state of emotion (Tripathi, 2019). It is also about decision making intelligence regarding motion performed or say the action performed in environment by human. In a socially interactive assist robot in an environment of home, hospital, office etc. emotion is important for decision making and to perform action.

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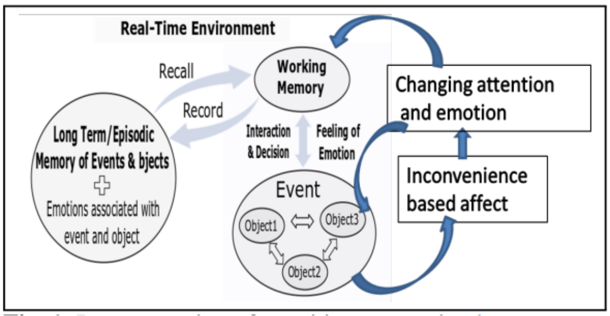

Fig. 1: Representation of cognitive connection between memory, working memory, event, objects and emotion

Moreover, emotion is helpful to define the behaviour and even to give personality to robot in Human robot interaction. Autonomy of motion and intuitive Sense (Tripathi et al., 2015) and Emotion and its role in decision for action (Tripathi, 2019) are the previous work produced by the author. In this paper both major concept 1. Autonomy of motion and intuitive Sense and 2. Emotion and its role in decision for action, is further extended as inclusive concept of Human Robot Interaction.

Autonomy and Supervision of Motion

Autonomy of motion is a perception action cycle performed without supervisory and the motion is generated with repeated learning of motion behaviour. However, there is switch between the autonomy to supervisory mode with 'awareness' that leads consciousness for supervision of motion based on interactive feedback from environment. This switch between the autonomy to supervisory depends on feeling of comfort/discomfort during motion and interaction with the environment. Both internal state and interaction with environment may lead to change in feeling of discomfort. For example, a learned motion pattern can be described by joint trajectory that is the series of well learned positions joints of the body performing the motion. As autonomy of motion is to follow this sequences and control system with internal feedback control pursuit to achieve the learned trajectory both position and temporal way. However, this autonomous control system is a kind of passive effort to minimize the both trajectory and temporal, which may lead to error exceeding temporal and position boundary range. An excess to position and temporal range can be supervised for comfortable motion by switching from autonomy to supervisory mode based of 'awareness' to feeling of discomfort.

Emergence of consciousness towards state of physical discomfort and realization of the feeling of discomfort evolves with physical and emotional awareness as represented in Fig. 2. This can be seen in view of neurocognitive system of conscious 'aware state' as internal sensory system and peripheral systems of autonomy. A behaviour model that can recognise, reason and analyses the problem of discomfort will provide improved motion or interaction by smooth switching between autonomy to aware state.

Emotion and its Role

Sigmund Freud gave the theory of mind based on philosophical approach of psychology, which further redefined by Ledoux (1998); Bechara et al. (2000) based of ´ neuro-cognitive theories. On the basis of the neuro-cognitive theories mind consist of three levels conscious, preconscious and unconscious, where consciousness is the tip of ice-burg of mind. Ledoux further explains feelings and emotions exists at both subconscious and conscious levels. The subconscious level of emotion resulted by affective behaviours generated by 'low road' i.e. a fast limbic path from the thalamus to the amygdala.

The other conscious level emotion path is through 'high road' slow path route through sensory cortex. In case of 'high road' subjective experience of emotion based on sensory information processing make it slow, where 'low road' case feeling of emotion is more like physiological and behavioural response, a kind of fast reflex. William James (Zajonc, 1980; Reisenzein et al., 1995; Friedman, 2010) explains the 'low road' as: Stimulus feelings responses and 'high road' as: Stimulus (event) responses (reactions) subjective feelings (emotions). William James further explains it an action response of fight or fight, flight when feeling of fear precedes and it can be concluded as stimulus physical responses feedbacks, whereas fight is cognitive system emotions physical responses, and it is performed by the emotion specific Autonomic Nervous System (ANS).

Cannon (1930) focused on sympathetic nervous system functionality as it works as a part of autonomic nervous system for emergency response in situation of fight or fight. Based on his study, Cannon criticised William James that racing heart and sweating like physical responses governed by sympathetic nervous system are relatively slow and cognitive system that express emotions fast enough to miss this slow response recognition. That means arises faster than physical response like sweating and dry throat etc.

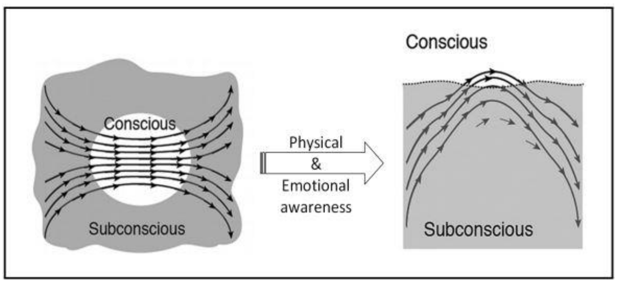

Fig. 2: A graphical representation of subconscious and conscious dynamics

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Ledoux (1998; 2012) clarifies the Cannon and Williams hypothesis conflicting on whether emotion or physical response which is first? Ledoux find this which is first view point inconsistent as emotion can be seen with two different aspects of emotion, 1. Emotion as state of mind, 2. Emotion associated with emotion-specific physical response. One reason of this conflict was graph or the flow diagram representing this process, and the question of which is first arises due to that. This also shows the limitation of functional block representation in modelling and flow diagram representing the dual aspect regarding process of emotion.

Zajonc (1980) performed experiment in which stimuli presented to the unconscious subjects still the subject can clearly determine a recognizes the stimulus according to the presentation order as their own preference, and reasoned that preference can be controlled subconsciously, that is a kind of subliminal effects. With this evidential reasoning Zajonc also explains that there is no necessity to reason the which is first. Similar experiment performed by Ben-Zeeva et al. (2005) shows the unconscious subject affective response to stereotype threat supporting Zajonc. Experiment by Zajonc and Ben-Zeeva suggest or rather approve that emotion is multidimensional, and one kind of emotion can be represented by a vector in a multidimensional space of emotion, like it been simplified by Plutchik's diagram (Plutchik, 1979)

In a previous work (Tripathi, 2019) the author represented emotion model for a robot based on Plutchik's representation of emotion as vector in a multidimensional space. The author enhanced the Plutchik's representation by adding another dimension as level of the emotion which changes action in interactive environment. With due consideration that emotion plays a vital role in motion and action in this paper the author proposed the cognitive aspect of emotion, motion related emotion and how human robot interaction progress based on that.

Mathematical Framework for Motion Autonomy, Supervision and Emotion

To understand the motion autonomy and supervision requirements Fig. 3 shows three situations as:

1. planned (learned) trajectory
2. Autonomous Level
3. In need of supervision

A planned (learned) trajectory is executed as autonomous level with executed trajectory having deviation from learned trajectory in bounded space of x, y, t as shown in Fig. 4 (2). However, when the x y value with respect to 't' goes beyond these boundary condition it need to be supervised well to bring back to value within the boundary space as shown in Fig. 4 (3) need of supervision.

However, there is another question that how this transition from autonomy to supervised learning transition can take place. The three types of modeling proposed by Vernon et al. (2007); Vernon (2008) for which may be considered as prospective background for this transition are as:

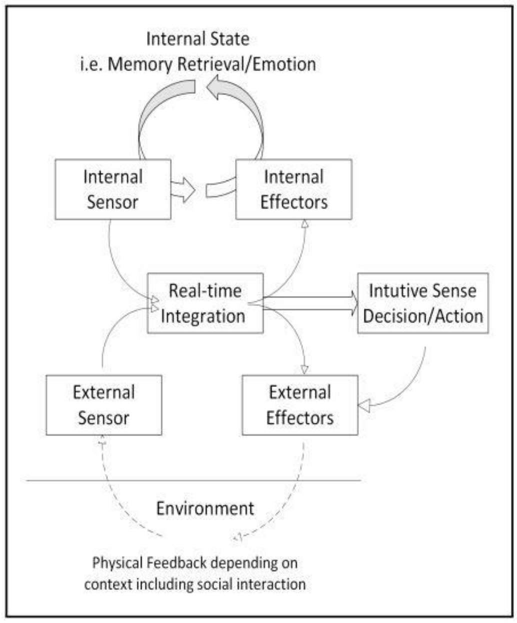

Fig. 3: A prospective model representing autonomy and its supervision based on Tani (2009); Weng (2004a-b; 2023); Vernon et al. (2007)

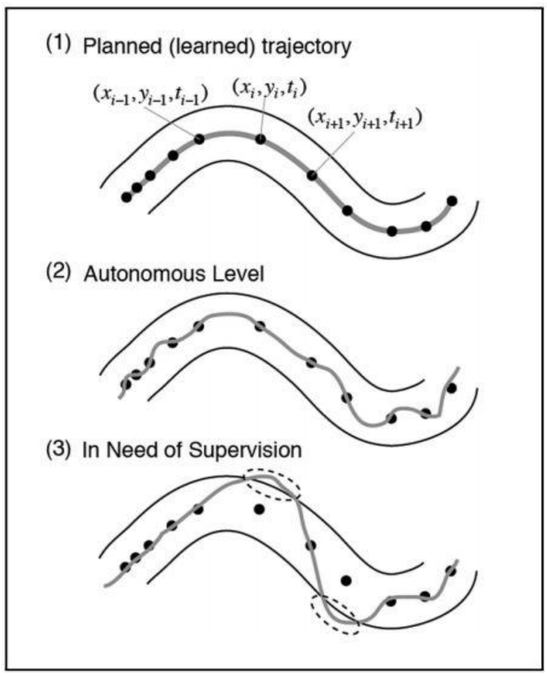

Fig. 4: An example representation of planned, autonomous and supervision trajectory

1. Characteristic: Showing some rule based characteristic of state change
2. Cognitivist: Showing the probabilistic state change
3. Emergent: State change is based on emerging physical discomfort and its recognition

A computational framework based on these modeling is explained by Tripathi et al. (2015). A characteristics model can be represented by continuous time model representing the dynamics of chance can be given as qt = R (t,qt ; γ) where qt and γ respectively denote state-vectors of time 't' and a set of parameters as a constant. On the other hand, the cognitivist type can be represented as a probabilistic model with abstract symbolic representations of cognitive state. An example given as Pr = L (qt |qt−1, qt−2.; γ) mathematically represents probabilistic occurrence of the states qt. The third type is emergent type which is also consistent to (Tani, 2009) explanations regarding function of the anticipation, as emerging consequence of memory retrieval and decision-making process and (Weng, 2004a-b; 2023; Vernon et al., 2007) automatic and predictable state emergence system for robots. An example of such emergence can be interpreted with respect to the Fig. 4 where occurrence state transition from autonomy to supervision occurs due to emergence of x,y value with respect to 't' goes beyond boundary value. So, if qt combined represent state of x,y at time 't' a dynamical model may be given as q = f(q,q˙,q¨; γ) where q˙, q¨ will represent 1st and 2nd derivative of 'q' that is basically derivation x,y. If x,y represents the position in space then q˙ and q¨ will represent the velocity and acceleration. In a situation where state where q¨ goes beyond boundary value of acceleration (maximum jerk), give emergence to a physical damage, hence emotion and feeling of pain.

To consider the emotion and motion interactively as a state of robotic system representing motion x, y at time 't' and emotion 'E'. (Tripathi, 2019) given emotion model for a robot based on Plutchik's representation of emotion as vector Fig. 5, where emotion formulated as E = f (θ, r, z) . Model represents different modalities of emotion by value of signal 'θ' as −180<θ<180. Variable 'r representing the level of emotion at particular time, and 0 < z < 1 showing the level of attention, as level of emotion affectively associated with level of attention. Occurrence of change in emotion state appears due to an event or object appearance in the environment. The internal representation of object in robot memory associates the values θ,r and z. The associated value θ,r is corresponding to the emotion that object or event evokes in robot.

Possible Event and Action for an Emotion Type

The following tables are present some of the possible event and action for a emotion type that occurs generally and shows the prospect of human robot interaction.

Tables 1-5 shows cause and action for human and robot for 5 main emotion Fear, Sadness, Anger, Joy and Love. The table is useful for event based human robot interaction and robot response. However, setting up an environment for concrete execution of such event and response is a challenging task.

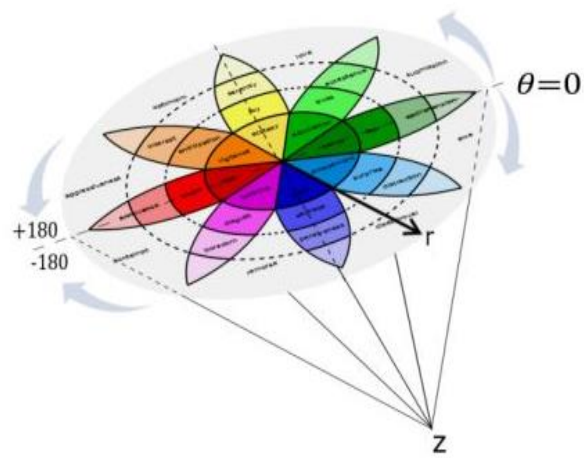

Fig. 5: Plutchik's representation of emotion with attention represented by z value

Table 1: Emotion Fear: Human Robot Interaction Prospect

Human		Robot	
Cause	Reaction	Cause	Reaction
Threat of social rejection	Sweating, perspiring	Fearof collision or fall	Stop action, Sense the environment showing fear
Possibility of lose and failure	Feeling nervous, jittery, jumpy	BeingIn Dark	Sitting onsame position Freezing
Losing control or competence	Shaking, quivering, trembling	Possibility of failure (Battery Low)	Freezing and Asking someone to put on charging
Threat of harm or death	eye darting looking quickly around	Losing control (Battery Low)	Freezing and Asking someone to put on charging, or having self-motion to charging point

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Table 2: Emotion Sadness: Human Robot Interaction Prospect

Human		Robot	
Cause	Reaction	Cause	Reaction
Undesirable outcome, negative surprise	Sitting or lying down(being inactive)	Failure attempt	sad expression for moment, If battery ok try again
Deathof Loved one	Tired rundown low energy	Power less	sadly asking for charging and sit
Rejection Exclusion Disapproval Slow	Shuffling movement	Empathy with someone sad	Trying to make happy by dance and song
Not getting what was wanted	slumped droofing posture	Empathy with someone sad	Showing empathy with speech, Giving hug

Table 3: Emotion Anger: Human Robot Interaction Prospect

Human		Robot	
Cause	Reaction	Cause	Reaction
predispositi of anger	onObscenities, cursing	Unwanted touch	Annoyed showing anger
Reversal of loss of power, status	verbally attacking the cause of anger	Someone touching or taking the Liked thing	Annoyed showing anger
violation of expectation	Loud voice, yelling, Screaming	Calling But no answer	Annoyed showing anger

Table 4: Emotion Joy: Human Robot Interaction Prospect

Human		Robot	
Cause	Reaction	Cause	Reaction
Task success achievement	Being courteous, friendly To others Task	success full	Showing joyful action
Desirable Out com; getting what was wanted	Doing nice things for others	Master praising	Joyful attention
Receiving esteem, respect, praise	Communica the good feeling	tingGetting red ball	Happiness with joy
getting something striving for	sharing the feeling	Receiving love and affection from master	Happiness with joy

Table 5: Emotion Love: Human Robot Interaction Prospect

Human		Robot	
Cause	Reaction	Cause	Reaction
Other offer something wanted	Wanting the best for other	Someone giving something wanted (Red Ball)	Thank you showing feeling
Person knows other loves, needs him or her	Wanting to see and spend time with other	Someone known shows affection and Love	Sayin I love you. Love feeling
person find other attractive	Saying I love you	Someone plays with	Thank you showing feeling
exceptionall good communicat	y Expressing positive ionfeeling to others	Talking politely and showing love	Saying I love you. Love feeling

Discussion

As motion and motion-based action and event is also consider to triggering specific emotion, the proposed frame work for human robot interaction is an effort in a direction of integrating cognitive dynamics of emotion and motion. In introduction paper explains the cognitive interaction of episodic memory, working memory emotion and interaction as event and motion/action. In the next section the motion and action autonomy and supervision is explained as how consciousness emerge for supervision. Further, it is also interesting how emotion and its role affect the decision and action which is explained in section III.

Overall the paper gives a framework for human robot interaction with cognitive dynamics of motion and emotion. Table 6 concludes about the contribution in prospective of Human robot interaction for two earlier used methods and proposed method, 1. Emotion model for a robot and 2. Method to evaluate intuitive sense for motion 3. Inclusive Method: Emotion and motion.

Table 6: Human Robot Interaction Prospect with Autonomy with Intuitive Sense and Emotion

Method/approach	Contribution	Human Robot Interaction Prospect
Emotion model for a robot	Internal state of emotion represented based on event, object	Decision of action and interaction based on internal state
Method to evaluate intuitive sense for motion	An intuitive sense of Autonomy or supervision	Action and interaction based on intuitive sense
Inclusive Method: Emotion and motion	human centered interaction as Emotion state is inclusive to intuitive sense of motion	Action and interaction based on emotion inclusive intuitive sense

Conclusion

The paper is effort to explains the theoretical cognitive background and a computational method to represent motion and emotion integration for robotic implementation. The main challenge in implementation of such framework is to have a concrete robotic environment to implement the it to robotic behaviour level and show the human robot interaction in a working setup. Small humanoid type legged robot or wheeled type upper body humanoid robot supposed to be effective robotic tool for such cognitive framework. Another level of challenge is to not just motion but also sensing capability of robot, both in terms of internal sensing of robot condition and environment sensing capability. It is expected to develop the setup to implement robotic framework to show the human robot interaction as future work.

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Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

References

Bechara, A., Damasio, Hanna, & Damasio, A. R. (2000). Emotion, Decision Making and the Orbitofrontal Cortex. Cerebral Cortex, 10(3), 295–307. https://doi.org/10.1093/cercor/10.3.295

Ben-Zeeva, T., Feinb, S., & Inzlichtc, M. (2005). Arousal and stereotype threat. Journal of Experimental Social Psychology, 41(2), 174–181. https://doi.org/10.1016/j.jesp.2003.11.007

Cannon, W. B. (1930). Bodily Changes in Pain, Hunger, Fear and Rage: An Account of Recent Researches Into the Function of Emotional Excitement. 14. https://doi.org/10.1210/endo-14-1-33a

Cicerone, K. D., Dahlberg, C., Malec, J. F., Langenbahn, D. M., Felicetti, T., Kneipp, S., Ellmo, W., Kalmar, K., Giacino, J. T., Harley, J. P., Laatsch, L., Morse, P. A., & Catanese, J. (2005). Evidence-Based Cognitive Rehabilitation: Updated Review of the Literature from 1998 Through 2002. Archives of Physical Medicine and Rehabilitation, 86(8), 1681–1692. https://doi.org/10.1016/j.apmr.2005.03.024

Friedman, B. H. (2010). Feelings and the body: The Jamesian perspective on autonomic specificity of emotion. Biological Psychology, 84(3), 383–393. https://doi.org/10.1016/j.biopsycho.2009.10.006

LeDoux, J. (2012). Rethinking the Emotional Brain. Neuron, 73(4), 653–676. https://doi.org/10.1016/j.neuron.2012.02.004

Ledoux, J. E. (1998). The Emotional Brain: The Mysterious Underpinnings of Emotional Life.

Marieb, E. N., & Hoehn, K. N. (2012). Human Anatomy and Physiology.

Plutchik, R. (1979). Emotion: A Psychoevolutionary Synthesis.

Ramachandran, V. S., & Blakeslee, S. (1998). Phantoms in the Brain: Probing the Mysteries of the Human Mind. 396.

Reisenzein, R., Meyer, W.-U., & Schützwohl, A. (1995). James and the physical basis of emotion: A comment on Ellsworth. Psychological Review, 102(4), 757–761. https://doi.org/10.1037//0033-295x.102.4.757

Smith, J. (2020). Emotion modeling in robotics. Journal of HRI, 12(3), 45–60.

Tani, J. (2009). Autonomy of Self at Criticality: The Perspective from Synthetic Neuro-Robotics. Adaptive Behavior, 17(5), 421–443. https://doi.org/10.1177/1059712309344421

Tripathi, G. N. (2019). Emotion Model for a Robot. Cyber-Physical Systems for Social Applications, 86–97. https://doi.org/10.4018/978-1-5225-7879-6.ch005

Tripathi, G. N., Chik, D., & Wagatsuma, H. (2013). How Difficult Is It for Robots to Maintain Home Safety? – A Brain-Inspired Robotics Point of View. Springer, 528–536. https://doi.org/10.1007/978-3-642-42054-2_66

Tripathi, G. N., Wagatsuma, H., Dimitrova, M., Vircikova, M., & Sinčák, P. (2015). A Method to Evaluate Intuitive Sense by Using a Robotic Tool: Towards Engineering for Assistive Technology and Accessibility. Lecture Notes in Computer Science, 561–569. https://doi.org/10.1007/978-3-319-20681-3_53

Van, V. W. (2009). Minding time in an amodal representational space. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1525), 1815–1830. https://doi.org/10.1098/rstb.2009.0023

Vernon, D. (2008). Cognitive vision: The case for embodied perception. Image and Vision Computing, 26(1), 127–140. https://doi.org/10.1016/j.imavis.2005.08.009

Vernon, D., Metta, G., & Sandini, G. (2007). A Survey of Artificial Cognitive Systems: Implications for the Autonomous Development of Mental Capabilities in Computational Agents. IEEE Transactions on Evolutionary Computation, 11(2), 151–180. https://doi.org/10.1109/tevc.2006.890274

Wagatsuma, H., & Tomonaga, Y. (2011). Problems of temporal granularity in robot control: Levels of adaptation and a necessity of self-confidence. The 2011 International Joint Conference on Neural Networks, 2670–2675. https://doi.org/10.1109/ijcnn.2011.6033568

Weng, J. (2003). A theory for mentally developing robots. Proceedings 2nd International Conference on Development and Learning. ICDL 2002, 131–140. https://doi.org/10.1109/devlrn.2002.1011821

Weng, J. (2004a). Developmental robotics: theory and experiments. Int. J. Human. Rob, 1(2), 199–236.

Weng, J. (2004b). A Theory of Developmental Architecture. Proceedings of the 3rd International Conference on Development and Learning (ICDL 2004), La Jolla, 31–38.

Zajonc, R. B. (1980). Feeling and thinking: Preferences need no inferences. American Psychologist, 35(2), 151–175. https://doi.org/10.1037/0003-066x.35.2.151