What Lies Beneath—A Survey of Affective Theory Use in Computational Models of Emotion (Supplementary Material)

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1 Search Protocol

We created a search protocol following the PRISMA-S guidelines [1] to answer the question:

What emotion theories do designers use to build their emotion-generating Computational Model of Emotion (CME)? Why do they use these theories?

1.1 Information Sources and Methods

1) Databases Searched
   - IEEE Xplore
   - ACM Digital Library
   - AAAI Digital Library
   - SpringerLINK
   - ScienceDirect (Elsevier)

   Rationale: These encompass some of the major organizations that publish work in affective computing as conference proceedings and journals. They tend to be limited to English publications only.
2) Multi-Database Searching
   - Not used
3) Study Registries
   - Not applicable
4) Online Resources and Browsing
   The following publications are published online, listed by the database where they are located.
   One author examined their table of contents (TOC) by hand for relevant papers. Paper relevancy was assessed by its title and abstract. The author examined the paper contents if relevancy could not be determined from the title and abstract.
   - IEEE Xplore
     - IEEE Transactions on Affective Computing
     - IEEE Transactions on Computational Intelligence and AI in Games
   - ACM Digital Library
     - Proceedings of the ACM International Conference on Intelligent Virtual Agents
   - SpringerLINK
     - Proceedings of the International Conference on Intelligent Virtual Agents
     - Proceedings of the International Conference on Agents and Artificial Intelligence (Selected and Revised Papers)

   Rationale: They were selected due to their focus on intelligent virtual agents.
5) Citation Searching
   The references/citations listed in papers found using Databases [Section 1.1, Item 1] and Online Resources and Browsing [Section 1.1, Item 4] were manually screened for potential papers.
   Rationale: Part of understanding why a design decision was made is understanding the influences on it. Here, that includes cited CMEs. This method also reduces the probability of missing a CME that frequently appears in the literature reviews of subsequent ones, as there is a high probability of multiple papers citing it directly, or citing another paper that leads back to it.
6) Contacts
   - Not used
7) Other Methods
   Some papers were found by fellow researchers in the course of their own searches. One author examined these by hand for relevancy. Paper relevancy was assessed by its title and abstract. The author examined the paper contents if relevancy could not be determined from the title and abstract.
   Rationale: There were few papers gathered this way, so it was worth examining them in case they were not found by other search strategies (Section 1.2).

1.2 Search Strategies

1) Full Search Strategies
   The initial search was done following strategy (a) to gather results from databases (Section 1.1, Item 1). Additional results were added after searching online resources (Section 1.1, Item 4) and other methods (Section 1.1, Item 7).
   After reducing the results using paper eligibility criteria (Section 1.2, Item 3), strategy (b) was executed on

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the papers in the reduced list to gather results from citations (Section 1.1, Item 5).

a) Keyword Search

i) IEEE Xplore
Search executed from `Advanced Search > Command Search`. Query split into two parts due to limitation on wildcard (*) characters.
Search results were downloaded as a CSV file using IEEE Xplore's built in `Export` function.
- ((″comput* model*″) AND ″emotion*″) NOT (″recognition*″ OR ″predict*″)
- (″affective comput*″ OR ″comput* emotion engine*″ or ″emotion engine″) NOT (″recognition*″ OR ″predict*″)

ii) ACM Digital Library
Search executed from `Advanced Search` using `The ACM Full-Text Collection` and `Search Within ''Anywhere''`. Query split into three parts to manage search terms.
Search results were downloaded by navigating to each results page, checking `Select All` and using `Export Citations` to download a text file of the results in `ACM Ref` format.
- ″computational emotion model″ OR ″computational emotion models″ OR ″computational model of emotion″ OR ″computational models of emotion″ -predict* -recognition*
- ″affective computing″ -predict* -recognition*
- ″emotion engine″ OR ″computational emotion engine″ -predict* -recognition*

iii) AAAI Digital Library
Search executed from the search bar at the top right corner of www.aaai.org. There are no Advanced Search functions.
Since the AAAI Search function is a "Google Custom Search" and limits the results to the first 10 pages, these searches were repeated in `Google Search` by prepending `site:www.aaai.org` to each query.
There was no method for exporting search results, so each item was examined individually. Potential relevant results were manually saved in an Excel sheet.
- computational model of emotion -recognition* -predict*
- emotion engine -recognition* -predict*
- affective comput* -recognition* -predict*

iv) SpringerLINK
Search executed from the main search bar. Searches do not include wildcards because search function is designed to look for words with the same "stem" (e.g. "computer" also finds "computes" and "computation").
Search includes "Include Preview-Only Content".
Search was filtered by subdisciplines [Section 1.2, Item 2b].
Search results were downloaded as a CSV file using SpringerLINK's built in `Download` function.
- computational model of emotion NOT predict NOT recognition
- emotion engine NOT predict NOT recognition
- computational emotion engine NOT predict NOT recognition
- affective computing elicitation generation NOT predict NOT recognition

v) ScienceDirect (Elsevier)
Searches executed with `Advanced Search` to search for articles rather than journals. They were filtered by Publication Title [Section 1.2, Item 2c].
Searches capture spelling variations (e.g. "color" and "colour") and plural forms of search terms.
Search results were downloaded by navigating to each results page, checking `Select All` and using `Export` to download a text file of the results as citations.
- computational model of emotion -recognition -prediction
- affective computing generation elicitation -recognition -prediction
- emotion engine -recognition -prediction

b) One author screened the reference lists of included papers found from [Section 1.2, Item 1a] by hand for relevancy. Paper relevancy was assessed by its title and abstract. The author examined the paper contents if relevancy could not be determined from the title and abstract.

2) Limits and Restrictions
Papers were limited to those in English because it is a language shared by both authors. Specific database restrictions were as follows:

a) IEEE Xplore, ACM Digital Library, and AAAI Digital Library
No additional restrictions.
Rationale: These databases specialize in electrical, computer, and software engineering, and computer science. There was little chance that papers from unrelated fields would be captured in the search.

b) SpringerLINK
Search results are limited to the sub-discipline of "Artificial Intelligence".
Rationale: Of the available sub-disciplines, this most closely matched the kinds of CMEs that the authors wished to examine. Limiting results to this sub-discipline better focused the results so that there were fewer to examine by hand.

c) ScienceDirect (Elsevier)
Search results restricted to the following Publication Titles:
- Biologically Inspired Cognitive Architectures
- Cognitive Systems Research
- Computers & Education
- Computers & Graphics
- Computers in Human Behaviour
- Expert Systems with Applications
- Information and Software Technology
- International Journal of Human-Computer Studies
- Journal of Systems and Software

- Knowledge-based Systems
- Neurocomputing
- Procedia Computer Science
- Trends in Cognitive Sciences

Rationale: These journals were specifically targeted for their focus on computer science and engineering.

3) Paper Eligibility Criteria
One author examined the results gathered from the search strategies (Section 1.2, Item 1) for papers to include in the survey using the following criteria:
Inclusion Criteria

- Papers describing CMEs with an emotion generation/elicitation/appraisal component that is built on at least one emotion theory
Rationale:
  - Directly relates to research question
  - Disqualifies CMEs that use empirical data, neurology/brain anatomy, and psychological/sociological theories of human behaviour
  - Disqualifies CMEs that do not have an emotion generation component
- Papers representing the most recent version of a CME that had emotion generation-related design decisions (i.e. CME is given the same/variation of a name, has at least one common author, has the same designer intent, and uses the same emotion theories as its predecessors)
Rationale:
  - Assumes that the most recent paper reflects current understanding of CME requirements and available emotion theories

Exclusion Criteria

- Papers describing experiments on/with CMEs where a previously published paper describes the design of that CME
Rationale:
  - Do not focus on the CME's design or why decisions were made, therefore they do not serve research question
  - Citation Searching (Section 1.1, Item 5) would find paper(s) describing the design of these CMEs
- Papers describing CMEs that are solely/primarily combinations of other CMEs
Rationale:
  - Do not help understand why the component CMEs made their design decisions, therefore they do not serve research question
  - Citation Searching (Section 1.1, Item 5) would find paper(s) describing the design of component CMEs
- Papers that are surveys or describe design guidelines/frameworks
Rationale:
  - Do not directly serve research question
  - Citation Searching (Section 1.1, Item 5) would find additional paper(s) describing CMEs discussed
- Papers that describe CMEs designed solely on brain structures and/or empirical data
Rationale:
  - Do not directly serve research question

4) Search Filters
   - Not used
5) Prior Work
   - Not used
6) Updates
All searches rerun at worst three months prior to submission on June 14th, 2022.
7) Dates of Searches
Table 1 lists the last dates that full search strategies were executed (Section 1.2, Item 1).

1.3 Peer Review

Two research librarians, one familiar with surveys, reviewed the protocol. Their feedback resulted in a more thorough list of databases to search, and eliminated the need for Google Scholar results.

1.4 Managing Records

1) Total Records
Table 2 lists the total records found using Keyword Search (Section 1.2, Item 1a).
2) Deduplication
Search results were manually combined in an Excel spreadsheet, then sorted by "Title" and "Author(s)" to identify potential duplicate papers. These were manually removed so that there was only one record per unique paper.

2 CME "GENEALOGY"

Table 3 highlights some key systems that contributed to the design of a CME.

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TABLE 1
Date Searches Were Last Executed

Source	Last Run Date
IEEE Xplore	
((”comput* model*”) AND ”emotion*”) NOT (”recognition*” OR ”predict*”)	April 21, 2022
(”affective comput*” OR ”comput* emotion engine*” or ”emotion engine”) NOT (”recognition*” OR ”predict*”)	April 21, 2022
ACM Digital Library	
”computational emotion model” OR ”computational emotion models” OR ”computational model of emotion” OR ”computational models of emotion” -predict* -recognition*	April 25, 2022
”affective computing” -predict* -recognition*	April 25, 2022
”emotion engine” OR ”computational emotion engine” -predict* -recognition*	April 25, 2022
AAAI Digital Library	
computational model of emotion -recognition* -predict*	April 26, 2022
emotion engine -recognition* -predict*	April 26, 2022
affective comput* -recognition* -predict*	April 26, 2022
SpringerLINK	
computational model of emotion NOT predict NOT recognition	April 26, 2022
emotion engine NOT predict NOT recognition	April 26, 2022
computational emotion engine NOT predict NOT recognition	April 26, 2022
affective computing elicitation generation NOT predict NOT recognition	April 26, 2022
ScienceDirect (Elsevier)	
computational model of emotion -recognition -prediction	April 29, 2022
affective computing generation elicitation -recognition -prediction	April 29, 2022
emotion engine -recognition -prediction	April 29, 2022
Online Resource Browsing	
IEEE Transactions on Affective Computing TOC	April 22, 2022
IEEE Transactions on Computational Intelligence and AI in Games TOC	April 22, 2022
Proceedings of the International Conference on Intelligent Virtual Agents TOC	May 2, 2022
Proceedings of the ACM International Conference on Intelligent Virtual Agents TOC	May 2, 2022
Proceedings of the International Conference on Agents and Artificial Intelligence (Selected and Revised Papers) TOC	May 2, 2022

TABLE 2
Total Records Found with Keyword Search

Source	Total Results
IEEE Xplore	
((”comput* model*”) AND ”emotion*”) NOT (”recognition*” OR ”predict*”)	565
(”affective comput*” OR ”comput* emotion engine*” or ”emotion engine”) NOT (”recognition*” OR ”predict*”)	1,069
ACM Digital Library	
”computational emotion model” OR ”computational emotion models” OR ”computational model of emotion” OR ”computational models of emotion” -predict* -recognition*	32
”affective computing” -predict* -recognition*	465
”emotion engine” OR ”computational emotion engine” -predict* -recognition*	61
AAAI Digital Library	
computational model of emotion -recognition* -predict*	754
emotion engine -recognition* -predict*	169
affective comput* -recognition* -predict*	58
SpringerLINK	
computational model of emotion NOT predict NOT recognition	7,213
emotion engine NOT predict NOT recognition	1,061
computational emotion engine NOT predict NOT recognition	537
affective computing elicitation generation NOT predict NOT recognition	37
ScienceDirect (Elsevier)	
computational model of emotion -recognition -prediction	501
affective computing generation elicitation -recognition -prediction	134
emotion engine -recognition -prediction	282

TABLE 3
Overview of the Contributing Designs of CMEs

	System	Builds On
1	**AffectR**	–
2	**Cathexis**	–
3	**EmMod**	–
4	**FLAME**	–
5	**SCREAM**	AffectR (1), Em/Oz (66)[1]
6	**MAMID**	–
7	**TABASCO**	3T [2][2]
8	**WASABI**	MAX [3][3]
9	**Maggie**	–
10	**AKR**	Will (25)[2], GOLEM [4][2]
11	**GVH**	Autonomous Virtual Human Dialog System [5][3]
12	**ParleE**	Cathexis (2)[2], FLAME (4), Émile (28)[1,2], Em/Oz (66)
13	**IM-PMEB**	ALMA (41)
14	**GenIA**[3]	EMA (24), ALMA (41), ERDAMS (45), O3A [6][3], AgentSpeak [7][2]
15	**InFra**	FLAME (4)
16	**FAtiMA-M**	FAtiMA (37)[3], ORIENT [8][2], Computational Appraisal Architecture [9, pp. 31]
17	**HybridC**	EMIA [10][3,4]
18	**GEmA**	FLAME (4)[2]
19	**SOM**	–
20	**Soar**	Em/Oz (66)[1], PEACTIDM [11][2]
21	**LIDA**	Computational Appraisal Architecture [9, pp. 31]
22	**CLARION**	–
23	**ACRES**	–
24	**EMA**	AffectR (1), Soar (20)[2], Will (25)[2], Émile (28)
25	**Will**	ACRES (23)[3]
26	**ELSA**	–
27	**GAMA-E**	SocioEmo (59)[2], OCC Logical Formalism [12], GAMA [13][2]
28	**Émile**	AffectR (1), Cathexis (2)[1], Em/Oz (66), NML1 [14][2], Steve [15][5], Affect Editor [16][5]
29	**EMOTION**	GVH (11): Generic Model [17]
30	**HumDPM-E**	HumDPM [18][2]
31	**JBdiEmo**	Jadex [19][2]
32	**DETT**	MANA [20][1,2]
33	**EP-BDI**	–
34	**MicroCrowd**	Soar (20)[2]
35	**Puppet**	S3A (67)[2]
36	**CBI**	–
37	**FAtiMA**	TABASCO (7)[2], EMA (24), CBI (36), S3A (67), FearNot! [21][3]
38	**TARDIS**	Greta (40)[5], ALMA (41)[2], SocioEmo (59)[2]
39	**PUMAGOTCHI**	–
40	**Greta**	–
41	**ALMA**	EmotionEngine [22], [23][3]
42	**Eva**	ALMA (41)[2]
43	**PPAD-Algo**	ALMA (41), Eva (42)[2]
44	**Peedy**	–
45	**ERDAMS**	AffectR (1), ParleE (12)[1], DER [24], Émile (28)/"Jack and Steve"[1], Em/Oz (66), Corpora Coding [25][3]
46	**TEATIME**	–
47	**MMT**	–
48	**Presence**	PPP [26][2,3]
49	**POMDP-CA**	–
50	**iPhonoid**	Interactive Robot System with Memory [27][3], AEIS [28][2]
51	**EEGS**	Computational Appraisal Architecture [9, pp. 31]
52	**PWE-I**	HED [29][2], Mood Prediction [30][2]

Continued on next page

TABLE 3
(*Continued.*) Overview of the Contributing Designs of CMEs

	System	Builds On
53	**Kismet**	Cathexis (2)[3]
54	**R-Cept**	Vickia [31][2,5]
55	**GRACE**	EmotiRob [32][3]
56	**TAME**	–
57	**AEE**	–
58	**FeelMe**	–
59	**SocioEmo**	ParleE (12)[2], Émile (28), ALMA (41)[2], Em/Oz (66), E/P Model [33][3]
60	**The Soul**	ALMA (41)[2], Animating Expressions [34][3]
61	**GAMYGDALA**	Em/Oz (66)[1]
62	**MobSim**	ALMA (41)
63	**APF**	SocioEmo (59)
64	**MEXICA**	–
65	**NPE**	Emotional Planner [35], Possible Worlds Model [36][2,3]
66	**Em/Oz**	Tok [37][2], Hap [38][2]
67	**S3A**	Will (25)[4], Em/Oz (66)

[1] *For domain specific agent capabilities that are affective in nature, but have unclear theoretical roots.*
[2] *For domain specific agent capabilities that do not explicitly model agent emotion, influence emotion via other factors, map emotion to another affective type, or are implementation-specific.*
[3] *Direct or close descendant of this system.*
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