FROM NEWTON'S LAWS OF MOTION TO NATURAL LANGUAGE

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It is common knowledge that semantic role theory is still weakened by two related problems, viz. how semantic roles are to be determined; and what semantic roles there are. This paper advances a solution to the problems by deriving nine and only nine semantic roles from Newton's laws of motion which, using conventional notation, are statable as: $\mathbf{F} = m\mathbf{a} = 0$ (Newton I), $\mathbf{F} = m\mathbf{a} \neq 0$ (Newton II), and $\mathbf{F}_{1\rightarrow 2} = -\mathbf{F}_{2\rightarrow 1}$ (Newton III). First, it is postulated that when [$\mathbf{F} = m\mathbf{a} = 0$], **F**: [B/Z] and m**a**: [R], where B = change bearer, Z = non-change bearer, and R = reference. Second, when [$\mathbf{F} = m\mathbf{a} \neq 0$] obtains, **F**: [C/K] and m**a**: [E], where C = dynamic causer, K = static causer, and E = effected. Third, when [$\mathbf{F}_{1\rightarrow 2} = -\mathbf{F}_{2\rightarrow 1}$] is the case, $\mathbf{F}_{1\rightarrow 2}$: [N/T] and $\mathbf{F}_{2\rightarrow 1}$: [A], where N = dynamic contactor, T = static contactor, and A = contactee.

In order to probabilify this thetic metarule of realization of semantic roles by biomechanical forces a six-step method is adopted:

Step 1: determination of the biomechanical situation and application of the metarule
Step 2: determination of the logico-conceptual situation (in which y_1, y_2, y_3 feature as logico-conceptual entities)
Step 3: determination of the logico-conceptual equation
Step 4: determination of the logico-conceptual sequence
Step 5: determination of the functional sentence structure rule (in which the subject S, verb V, object O, complement C, and adverbial Adl feature)
Step 6: determination of the formal sentence structure rule (in which the noun phrase N", verb group Vg, adjective phrase A", subodinate clause S', adverb phrase Adv", and prepositional phrase P" feature)

We shall need in all seven cycles of application.

Cycle 1

(i) $\mathbf{F} = m\mathbf{a} = 0$ **F**: [B]; m**a** = 0: [Ø]
(ii) y_1B
(iii) $y_1B = y_1B$
(iv) $\langle y_1B + B\rangle$
(v) $\langle \underline{S} + \underline{V}\rangle$
(vi) $\langle N"_1 + Vg\rangle$

Cycle 2

(i) $\mathbf{F} = m\mathbf{a} = 0$ **F**: [B]; m**a** = 0: [Ø]
(ii) y_1B
(iii) $y_1B = y_1B$
(iv) $\langle y_1B + B\rangle$
(v) $\langle \underline{S} + \underline{V} + \underline{C}\rangle$
(vi) $\langle N"_1 + Vg + N"_2/A"/S'\rangle$

Cycle 3

(i) $\mathbf{F} = m\mathbf{a} = 0$ **F**: [B]; m**a** = 0: [R]
(ii) y_1By_2R
(iii) $y_1By_2R = y_1BR + By_2R$

(iv) $\langle y_1BR + BR + By_2R \rangle$

(v) $\langle \underline{S} + \underline{V} + \underline{Adl} \rangle$

(vi) $\langle N''_1 + Vg + N''_2/Adv''/S'/P'' \rangle$

Cycle 4a

(i) $\mathbf{F} = m\mathbf{a} \neq 0$ $\mathbf{F}$: [C]; $m\mathbf{a} \neq 0$: [E]

$\mathbf{F} = m\mathbf{a} = 0$ $\mathbf{F}$: [B]; $m\mathbf{a} = 0$: [Ø]

(ii) $y_1C[y_2B]E$

(iii) $y_1C[y_2B]E = y_1C[B]E + C[y_2B]E$

(iv) $\langle y_1C[B]E + C[B]E + C[y_2B]E \rangle$

(v) $\langle \underline{S} + \underline{V} + \underline{O} \rangle$

(vi) $\langle N''_1 + Vg + N''/S' \rangle$

Cycle 4b

(i) $\mathbf{F}_{1\rightarrow2} = -\mathbf{F}_{2\rightarrow1}$ $\mathbf{F}_{1\rightarrow2}$: [N]; $\mathbf{F}_{2\rightarrow1}$: [A]

(ii) y_1Ny_2A

(iii) $y_1Ny_2A = y_1NA + Ny_2A$

(iv) $\langle y_1NA + NA + Ny_2A \rangle$

(v) $\langle \underline{S} + \underline{V} + \underline{O} \rangle$

(vi) $\langle N''_1 + Vg + N''_2/S'/P'' \rangle$

Cycle 5

(i) $\mathbf{F} = m\mathbf{a} \neq 0$ $\mathbf{F}$: [C]; $m\mathbf{a} \neq 0$: [E]

$\mathbf{F} = m\mathbf{a} = 0$ $\mathbf{F}$: [B]; $m\mathbf{a} = 0$: [Ø]

(ii) $y_1C[y_2B]E$

(iii) $y_1C[y_2B]E = y_1C[B]E + C[y_2B]E$

(iv) $\langle y_1C[B]E + C[B]E + C[y_2B]E \rangle$

(v) $\langle \underline{S} + \underline{V} + \underline{O} + \underline{C} \rangle$

(vi) $\langle N''_1 + Vg + N''_2 + N''_3/A''/S' \rangle$

Cycle 6

(i) $\mathbf{F} = m\mathbf{a} \neq 0$ $\mathbf{F}$: [C]; $m\mathbf{a} \neq 0$: [E]

$\mathbf{F} = m\mathbf{a} = 0$ $\mathbf{F}$: [B]; $m\mathbf{a} = 0$: [R]

(ii) $y_1C[y_2By_3R]E$

(iii) $y_1C[y_2By_3R]E = y_1C[BR]E + C[y_2BR]E + C[By_3R]E$

(iv) $\langle y_1C[BR]E + C[BR]E + C[y_2BR]E + C[By_3R]E \rangle$

(v) $\langle \underline{S} + \underline{V} + \underline{O} + \underline{Adl} \rangle$

(vi) $\langle N''_1 + Vg + N''_2 + N''_3/Adv''/S'/P'' \rangle$

Cycle 7a

(i) $\mathbf{F} = m\mathbf{a} \neq 0$ $\mathbf{F}$: [C]; $m\mathbf{a} \neq 0$: [E]

$\mathbf{F} = m\mathbf{a} = 0$ $\mathbf{F}$: [B]; $m\mathbf{a} = 0$: [Ø]

(ii) $y_1C[y_2C[y_3B]E]E$

(iii) $y_1C[y_2C[y_3B]E]E = y_1C[C[B]E]E + C[y_2C[B]E]E + C[C[y_3B]E]E$

(iv) $\langle y_1C[C[B]E]E + C[C[B]E]E + C[y_2C[B]E]E + C[C[y_3B]E]E \rangle$

(v) $\langle \underline{S} + \underline{V} + \underline{O} + \underline{O} \rangle$

(vi) $\langle N''_1 + Vg + N''_2 + N''_3/S'/P'' \rangle$

Cycle 7b

(i) $\mathbf{F} = m\mathbf{a} \neq 0$ $\mathbf{F}$: [C]; $m\mathbf{a} \neq 0$: [E]

$\mathbf{F}_{1\to2} = -\mathbf{F}_{2\to1}$ $\mathbf{F}_{1\to2}$: [N]; $\mathbf{F}_{2\to1}$: [A]

(ii) $y_1C[y_2Ny_3A]E$

(iii) $y_1C[y_2Ny_3A]E = y_1C[NA]E + C[y_2NA]E + C[Ny_3A]E$

(iv) $<y_1C[NA]E + C[NA]E + C[y_2NA]E + C[Ny_3A]E>$

(v) $<\underline{S} + \underline{V} + \underline{O} + \underline{O}>$

(vi) $<N''_1 + Vg + N''_2 + N''_3/S'/P''>$

Our first major finding is that there is isomorphism between the logico-conceptual sequence, the functional and formal sentence structure rules. We may generalize the isomorphism as follows:

If $y_1\Pi_1y_2\Pi_2$ is a logico-conceptual situation with Π_1, Π_2 as metapredicates,

then $y_1\Pi_1y_2\Pi_2 = y_1\Pi_1\Pi_2 + \Pi_1y_2\Pi_2$.

Therefore, $<y_1\Pi_1\Pi_2 + \Pi_1\Pi_2 + \Pi_1y_2\Pi_2>$

$<\underline{S} + \underline{V} + \underline{C}/\underline{Adl}/\underline{O}>$

$<N''_1 + Vg + N''_2/A''/S'/Adv''/P''>$

Our second finding concerns the question whether natural-language predicates are generally reducible to the nine and only nine newtonian ones. To show that this is indeed the case, we informally consider the following reduction formulae:

(1) Cycles 4a and 5

$C[B]E \vdash [B]$

$<\underline{S} + \underline{V} + \underline{O}> \vdash <\underline{S} + \underline{V}>$

$<\underline{S} + \underline{V} + \underline{O} + \underline{C}> \vdash <\underline{S} + \underline{V} + \underline{C}> \vdash <\underline{S} + \underline{V}>$

(2) Cycle 6

$C[BR]E \vdash [BR]$

$<\underline{S} + \underline{V} + \underline{O} + \underline{Adl}> \vdash <\underline{S} + \underline{V} + \underline{Adl}>$

(3) Cycle 7a

$C[C[B]E]E \vdash C[B]E \vdash [B]$

$<\underline{S} + \underline{V} + \underline{O} + \underline{O}> \vdash <\underline{S} + \underline{V} + \underline{O}> \vdash <\underline{S} + \underline{V}>$

(4) Cycle 7b

$C[NA]E \vdash [NA]$

$<\underline{S} + \underline{V} + \underline{O} + \underline{O}> \vdash <\underline{S} + \underline{V} + \underline{O}>$

Our formalization of logico-conceptual situations, equations and sequences so far has been in terms of y_1, y_2, y_3. In order to achieve more specific formalizations we have to abandon y_1, y_2, y_3 in favour of a periodic table of conceptual elements which exhibits 26 entity variables.

The Periodic Table of Conceptual Elements

Period \ Group	1 B	2 Z	3 R	4 C	5 K	6 E	7 N	8 T	9 A
Abstract Entity	xB 1	xZ 2	xR 3	xC 4	xK 5	xE 6	xN 7	xT 8	xA 9
Meaning-Bearer	pB 10	pZ 11	pR 12	pC 13	pK 14	pE 15	pN 16	pT 17	pA 18
Quantity	qB 19	qZ 20	qR 21	qC 22	qK 23	qE 24	qN 25	qT 26	qA 27
Set	sB 28	sZ 29	sR 30	sC 31	sK 32	sE 33	sN 34	sT 35	sA 36
Number	nB 37	nZ 38	nR 39	nC 40	nK 41	nE 42	nN 43	nT 44	nA 45
Space (Length)	lB 46	lZ 47	lR 48	lC 49	lK 50	lE 51	lN 52	lT 53	lA 54
Form	φB 55	φZ 56	φR 57	φC 58	φK 59	φE 60	φN 61	φT 62	φA 63
Order	oB 64	oZ 65	oR 66	oC 67	oK 68	oE 69	oN 70	oT 71	oA 72
Direction	dB 73	dZ 74	dR 75	dC 76	dK 77	dE 78	dN 79	dT 80	dA 81
Degree	γB 82	γZ 83	γR 84	γC 85	γK 86	γE 87	γN 88	γT 89	γA 90
Matter	mB 91	mZ 92	mR 93	mC 94	mK 95	mE 96	mN 97	mT 98	mA 99
Time	tB 100	tZ 101	tR 102	tC 103	tK 104	tE 105	tN 106	tT 107	tA 108
Process	cB 109	cZ 110	cR 111	cC 112	cK 113	cE 114	cN 115	cT 116	cA 117
Force	aB 118	aZ 119	aR 120	aC 121	aK 122	aE 123	aN 124	aT 125	aA 126
Energy	eB 127	eZ 128	eR 129	eC 130	eK 131	eE 132	eN 133	eT 134	eA 135
Material Object	rB 136	rZ 137	rR 138	rC 139	rK 140	rE 141	rN 142	rT 143	rA 144
Living Thing	bB 145	bZ 146	bR 147	bC 148	bK 149	bE 150	bN 151	bT 152	bA 153
Plant	fB 154	fZ 155	fR 156	fC 157	fK 158	fE 159	fN 160	fT 161	fA 162
Animal	zB 163	zZ 164	zR 165	zC 166	zK 167	zE 168	zN 169	zT 170	zA 171
Human	hB 172	hZ 173	hR 174	hC 175	hK 176	hE 177	hN 178	hT 179	hA 180
Biophysical Willer	vB 181	vZ 182	vR 183	vC 184	vK 185	vE 186	vN 187	vT 188	vA 189
Perceiver	wB 190	wZ 191	wR 192	wC 193	wK 194	wE 195	wN 196	wT 197	wA 198
Cogitator	uB 199	uZ 200	uR 201	uC 202	uK 203	uE 204	uN 205	uT 206	uA 207
Valuer	gB 208	gZ 209	gR 210	gC 211	gK 212	gE 213	gN 214	gT 215	gA 216
Institution	iB 217	iZ 218	iR 219	iC 220	iK 221	iE 222	iN 223	iT 224	iA 225
Supernatural	kB 226	kZ 227	kR 228	kC 229	kK 230	kE 231	kN 232	kT 233	kA 234

The nine groups of the table accord with the nine newtonian predicates we derived from Newton's laws of motion. There are 26 periods of ascending conceptual complexity and 234 conceptual elements. We now turn to illustrate formalizations.

(1) A bull died.
zB

(2) The bull is dead.
zZ

(3) The door is open.
rZ

(4) The door opens.
rB

(5) The road widens.
lB

(6) The water is boiling.
mB

(7) The road becomes wide.
lB

(8) The book is on the table.
r_1Zr_2R

(9) The cook is boiling water.
hC[mB]E

(10) The clerk wrote a letter.
hC[rB]E

(11) The farmer slaughtered a bull.
hC[zB]E

(12) The warden opened the door.
hC[rB]E

(13) Kwame is learning French.
hNxA

(14) The girl kissed her boyfriend.
h_1Nh_2A

(15) The president appointed her minister.
$h_1C[h_2B]E$

(16) The child put the book on the table.
$hC[r_1Br_2R]E$

(17) The government detained him on the island.
iK[hZlR]E

(18) He opened the door for his guest.
$h_1C[rBh_2R]E$

(19) He opened the door with the key.
$h_1C[r_1C[r_2B]E]E$

(20) She paid Kwame a lot of money.
$h_1C[h_2NrA]E$

(21) The lecturer explained the theory of evolution to her students.

$h_1C[h_2NxA]E$

We conclude this paper with one major question:

How will this nascent "Newtonian" Grammar or Newtonian Grammar (NG) relate to Noam Chomsky's Universal Grammar (UG)?

References

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